

THE
Philosophical Works

Of the HONOURABLE

ROBERT BOYLE Esq;

Abridged, methodized, and disposed under the
GENERAL HEADS

OF

PHYSICS,
STATICS,
PNEUMATICS,

} NATURAL HISTORY,
} CHYMISTRY, and
} MEDICINE.

The whole illustrated with NOTES, containing the *Improvements* made in the several *Parts* of natural and experimental *Knowledge* since his time.

IN THREE VOLUMES.

By PETER SHAW, M. D.

L O N D O N:

Printed for W. and J. INNYS, at the *West-End* of St. Paul's;
and J. OSBORN, and T. LONGMAN, in *Pater-Noster-Row*.

M. DCC. XXV.

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44

THE DEDICATION

T O

The Right Honourable

The Lord *Burlington*.

MY LORD,

THE original philosophical writings of the Honourable Mr. *Boyle*, are a treasure worthy the cabinets of princes; and, perhaps, the most valuable present of that kind the world ever received. If my success in abridging them be answerable to my wishes, and the pains bestow'd in the attempt, I presume they will not, in this form, dishonour their noble author; nor prove unworthy the countenance and acceptance of your Lordship. At least I persuade my self it were injurious not to address the work to the noble family

The DEDICATION.

family of the *Boyles*, whereto the ties of nature, as well as affinity of genius, taste, and other qualifications shared in common with the great author, direct me.

May it, therefore, please your Lordship, to permit this first Volume of the Abridgment to bear your Lordship's name; whereby fresh honour will be derived to the noble author of the originals; and, in return, your Lordship's character be set in open view; since the works of Mr. *Boyle* confess the genius, taste, and temper so happily united in your Lordship.

I am,

MY LORD,

Your Lordship's most humble,

most obedient,

And most devoted Servant,

Peter Shaw.

A GENERAL
P R E F A C E
T O T H E
Abridgment of Mr. B O Y L E's
Philosophical Works.

THE philosophical writings of Mr. Boyle have, from their first appearing in public, done an honour to his country, and procured him a general esteem in the world. The novelty, the variety, the dignity, and the usefulness of the several subjects he treats, with the easy and familiar manner wherein they are handled, recommend his performances to the whole body of mankind: Mr. Boyle accommodates himself as well to the unlearned and the novice, as to the philosopher and the scholar; his whole scope and design being, with the utmost candour and simplicity, to communicate those numerous and important discoveries, which cost him infinite pains and application to make.

On the other hand, as Mr. Boyle was the introducer, or, at least, the great restorer of mechanical philosophy among us; so, by endeavouring to deliver himself in the most full and circumstantial manner about it, he has spun out his works to what, now that philosophy is more generally known, appears an immoderate length. His numerous pieces too being all publish'd occasionally, and in a miscellaneous manner, 'tis a matter of some difficulty to reduce them to an order fit for a ready and commodious perusal. Whence it is, that few having been at the

General Preface

pains to collect, methodize, and regularly study his excellent writings as they require, the value set upon them, tho' great indeed and general, falls vastly short of what they merit; proceeding rather from the report of here and there a diligent man, than from any personal and actual knowledge, that the generality, even of philosophers, had of them. But those who have been most conversant with Mr. Boyle, agree, that no author deserves better of mankind, or merits to be more generally read, than he. And, in order to procure him this general perusal, as nothing seem'd more conducive than to digest and contract his works into a just and regular abridgment, I was requested to attempt one. For, notwithstanding the Epitome of Mr. Boulton, a well digested, and compendious collection of all Mr. Boyle's philosophical writings, has been generally wish'd for, and declared, by unexceptionable judges, to be greatly wanting. 'Twas the opinion of such that principally determin'd me to the undertaking; and I shall think my labour well bestow'd, to have acquitted my self in it with their approbation.

The design of an abridgment, I conceive, is clearly to exhibit the whole substance of an author, without admitting any thing superfluous.

How far I have answer'd this end, in abridging the philosophical works of Mr. Boyle, is not for me to determine. It will be expected, however, that I give some account of my procedure herein.

Mr. Boyle's philosophical writings appearing to be a miscellany of essays, upon a great variety of subjects, it was judg'd convenient, in the first place, severally to reduce them under the respective general heads whereto they naturally belong'd; whence the scope and design of each separate piece, might presently become conspicuous; and the sense and tendency of the whole, thus rang'd, be the better judg'd of.

A farther advantage, I presumed, must accrue from placing them in such a manner, that those which were introductory or fundamental, might stand first, and prepare the way for the rest; and that all might naturally follow, mutually illustrate, and, as much as possible, prove, confirm, and lead to each other. To this end, likewise, it was found absolutely necessary

General Preface.

iii

to rectify numerous dislocations; to bring all Addenda and insertions into their proper places; and so to dispose and marshal the several scatter'd articles relating to the same subject, that they should together tend to compose one regular whole. But as Mr. Boyle never design'd to write a body of philosophy, only to bestow occasional essays on those subjects whereto his genius or inclination led him; 'tis not to be expected, that even the most exquisite arrangement, should ever reduce them to a methodical and uniform system, tho' they afford abundant materials for one.

In the next place, observing that Mr. Boyle's manner was, ceremoniously to address particular pieces to particular persons; to use large preparatory discourses, before he enter'd upon his design; and always to write in a copious, diffusive, and circumstantial style; I determin'd to leave out in the abridgment whatever was merely personal, or had no relation to the argument; and to contract his words into as small a compass as appear'd consistent with the perspicuity requisite in philosophical writings. And I should be sorry that any person, tho' a stranger to Mr. Boyle's discoveries, or the modern philosophy, should not, by the proper application, fully understand his doctrine in the abridgment; or not be enabled by it to go through all his experiments, processes, and operations, in the very manner wherein himself delivers them.

And because some exceptions have been taken to Mr. Boyle's originals, on account of the passages that frequently occur in different languages from that wherein he wrote, and the quaint, antiquated, or uncouth expressions he sometimes uses; it seem'd convenient to make him wholly English; to throw out the harsher words and phrases; and so far to alter the style, that it should not offend a merely philosophical ear: and to do more, in this respect, was deem'd an unnecessary labour. For, as I was all along to preserve the sense of the author pure from any foreign turn or tincture, it seem'd most expedient to employ his very words, wherever they appeared concise, expressive, and unexceptionable.

And these are the views I had, with regard to the author, in this undertaking.

General Preface.

Having now reduced Mr. Boyle's philosophical works under distinct general heads, I judg'd it would be acceptable, if to each were prefix'd some short account of the doctrine rang'd under it; that the reader might come a little prepared to the consideration thereof.

And to render this abridgment the more useful and satisfactory, it was judg'd requisite to add, by way of notes, the later discoveries and improvements, in the principal subjects treated of by Mr. Boyle. 'Twas far from my design in this, to write a comment upon the author; that were a work for some great master in natural and experimental knowledge. Conscious of my own inabilities, I design'd no more than to transfer from the great Sir Isaac Newton, and some few other eminent and successful inquirers into nature, such particulars as tended to illustrate, confirm, or improve, the doctrine and discoveries of Mr. Boyle.

What stands collected from various pieces of our author, and thrown together by way of general preface to his philosophical writings, will render it needless for me to enter into the particular nature, method, and design of them; or to answer the objections whereto they may seem liable: all this is there done by the author himself, in a manner superior to any I pretend to. I shall, therefore, only observe farther, as to my own part, that I have, thro' the whole course of the work, consulted the advantage of the reader, as well as the reputation of Mr. Boyle.

'Tis an equal regard to both, that here determines me to dwell a little upon the excellencies of the author; and the advantages to be reap'd from a perusal of his works.

Mr. Boyle takes up his reader at the elements, or fundamental principles of things, and with exquisite judgment conducts him thro' all the regions of nature, to furnish him with objects, whereon to exercise his faculties; and, being first solicitous to make him a general philosopher, leaves him prepared for any farther inquiry he shall think fit to make, into the works of nature or art.

The best and only solid foundation for philosophy, is its usefulness to mankind; and the only way to gain it the reputation it deserves, must be to manifest the great advantages that attend

General Preface.

V

attend the study thereof. Mr. Boyle has been every where careful to shew, that nothing can be more serviceable and beneficial in life, than experimental philosophy in general. The men of wit and learning have, in all ages, busied themselves in explaining nature by words; but it is Mr. Boyle alone, who has wholly laid himself out in shewing philosophy in action. The single point he perpetually keeps in view, is to render his reader not a talkative, or a speculative, but an actual and practical philosopher. Himself sets the example: he made all the experiments he possibly could upon natural bodies, and communicates them with all desirable candour and fidelity.

He well knew, that experiments are the life and soul of natural knowledge; and that no real improvement can therein be made without them. The framing of notions, and devising of schemes, may make a notional or ideal philosopher; but experiments alone, or the dealing with natural bodies, and applying them to each other, can make a real and actual one. Mr. Boyle has left us such an ample catalogue of trials, in all the parts of natural philosophy, and such foundations for farther discoveries, as can only be fully prosecuted and applied by the Boyles and the Newtons of future ages.

To the want of proper experiments, and the taste for reading and making them, must be attributed all our ignorance in natural things. What light has Mr. Boyle let into the dark parts of nature, barely by means of experiments! The foundation and main spring of his whole philosophy, is the obvious art of experimenting. But he was very far from devising and making experiments, in order to confirm or establish a system, raised without the help of them; for in that case, 'twas his opinion, the greatest advantage is lost, which might otherwise attend them. A man wholly possessed with any one view sees all things in the light of it; and slight whatever, at first sight, appears to have no tendency thereto. Thus the ancient, and some modern chymists, intent and fixed upon the melioration of metals, or transmutation, lost all the benefits of that infinite number of experiments they made, except what tended to their darling end. But if the mind be kept entirely open and disengaged, every phenomenon will be observed. And this was
Mr.

General Preface.

Mr. Boyle's manner of proceeding. Nay, after he had gone the greatest lengths he was able, he draws no dogmatical conclusions from his premises; well knowing, that the great discoveries still remaining to be made, may happen to clash with, or overturn any system, that, for want of light, might once appear rational and well founded. The generality of mankind are in post-haste to draw conclusions, before they have consider'd the premises; and usually determine off-hand upon a subject: but Mr. Boyle, after having well ponder'd his experiments and observations, and view'd them on all sides, with their several circumstances, is exceeding cautious in reasoning from them. He never raises an hypothesis to solve phenomena; but if the solution does not of it self grow out of them, when attentively consider'd, he leaves all as he found it; and waits for farther discoveries to inform him. This practice, as it commands our admiration, on account of its difficulty; so it highly deserves to be imitated, on account of its usefulness.

The business of experimenting he restrains not to any particular branch of science; but applies it, in full latitude, to all the elements, and all the bodies they mix with, or go to compose. The air, earth, fire and water, all are scrutiniz'd and tortured by experiments, to confess their natures, offices, uses, and the wisdom and design of their creation. 'Tis by this means that he shews us very various and surprizing properties and effects of that familiar fluid, the air or atmosphere; what numerous broods of effluvia float therein; how different bodies are affected by it, according to their different dispositions; its uses to the vegetable, animal, and mineral kingdom; how, like an immense ocean of a general menstruum, it acts variously upon all the bodies it surrounds, as different combinations of effluvia take their turns therein; whence numberless, unforeseen disorders in the animal aconomy, and ten thousand effects upon even inanimate bodies, which to vulgar eyes appear astonishing and unaccountable. 'Tis by this means, that he shews and explains, how the vast body of the earth is continually sending out her expirations into the atmosphere, and feeding vegetables from her superficial parts; whilst innumerable operations and chymical processes, are carrying on in her entrails; metals forming,

forming, stones growing, minerals mixing, sunning, subliming, firing, exploding, &c. Fire, that grand mystery of nature, he thus brings us acquainted with, whether solar, stellar, culinary, subterranean, or artificial, by finding out its various effects and operations upon bodies exposed to it; and shews us, that by rarifying their parts, mixing with them, lodging it self therein, altering their texture, increasing their gravity, and giving new modifications to the matter of them, it produces ten thousand varieties, and all the qualities and operations in natural bodies. The element of water he examines in like manner, describing its properties, effects, and the various forms it may assume, in all the different places, as the air, the earth, and even in consistent or the hardest of bodies, wherein 'tis found; tracing it from the clouds and rivers to the deepest seas, whose productions and concealed treasures, he, by experiment, lays open. He traces animals of all kinds, from their first sensible magnitude, to their full growth; and applies his experiments to them in every stage; whereby he shews us the first beginnings and increase of life; the ways whereby it may be restored, after it seems wholly to have left the body; that all living creatures are actual machines, so wisely contrived and set together, that their parts serve various purposes at once, without interfering with one another; that the loss of limbs in animals, is not absolutely irreparable; that some may long survive the want of their hearts and heads, and even propagate their species without them. In the vegetable kingdom, he shews us the rise and increase of trees and plants from water; the means of forwarding their growth, and making them fruitful; with the ways of preparing, improving, and preserving their products, and the various liquors they may be brought to afford. And in the mineral kingdom, he instructs us how all stony, metalline, and terrestrial bodies are form'd, grow, and ripen; shews us the steps that nature takes, in the several processes for their preparation; from what original matter they all spring; how gems assimilate, concrete, and harden; whence metals of all kinds; whence the ruby flames, the diamond sparkles, and gold obtains its lovely qualities. In short, he thus leads his reader thro' all the elements, and all the kingdoms in nature;

nature; sets to view and examines the several combinations, creatures, and productions of them; their properties, powers, virtues, uses, ways of working, &c. and this in the most instructive and entertaining manner. He shews us, that we inhabit a much wiser, and better regulated, a more active and instructive world, than is generally supposed; he makes us observe, that all the bodies around us are incessantly in action, and their parts in constant motion; that nature is perpetually carrying on her own grand schemes and designs, whether we regard them or not; that even our own bodies are, every moment, acted upon, affected, alter'd, and restored, by a vast variety of agents, which we little dream of. He does not barely amuse us with notions and speculations, but lays before us, and makes us see the important works of nature, wherein our selves, and all we possess, are nearly interested and concerned. Mr. Boyle calls out a thousand latent qualities in the air; a thousand useful substances from the bowels of the earth, and the depth of the sea. He greatly opens and dilates the mind; gives us noble and generous thoughts of nature, and of our own abilities; manifests that even desperate things may be attempted with success; and shews no quarter to the lazy, indolent temper of those, who, from shallow notions, and a want of having seen the powers in natural bodies, are for discouraging all new and grand undertakings; and uniting the knowledge of the philosopher, with all the freedom and address of the gentleman; he renders the most daring projects promising and advantageous. He will never allow us to consider the world as a rude heap of dull, inactive matter; but convinces us, that it is a grand and noble machine, continually actuated, inform'd, and govern'd by a most wise and beneficent Being, who keeps all the parts thereof in motion, and makes them act upon one another according to certain laws; then bringing us acquainted with these laws, he enables to make use of the same stratagems and contrivances, which nature her self employs; which, surely, are capable of performing the greatest things, when rightly applied; that is, when applied as Mr. Boyle, by his own example and experience, directs us. But he shews also, that in order to make the most advantageous use of these powers, a general knowledge of nature
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General Preface.

ix

is required. Without large and comprehensive views; without being well versed in mechanical arts, and the several branches of natural knowledge, so as to make one assisting to another, and all, in their turn, conspire to the same end, Mr. Boyle encourages no man to be a projector.

He is particularly cautious to guard his reader against every operation, that might any way prove dangerous or hurtful; and to prevent his imposing upon himself by any superficial observation, any fallacious or contingent experiment, whether made in his own person, or deliver'd by others. So much the more afflicting is it to find, that he shou'd himself be charged with having attributed too much to the power of nature and art; and to have easily credited uncertain accounts of things uncommon and extraordinary. In this particular I beg leave to dissent from the general opinion which has crept abroad of Mr. Boyle. From an attentive perusal of his admirable writings, I must, in justice to his memory, declare, that, in general, no author appears to have been more inquisitive into the foundations and evidence of the narratives he receives from others; or to have shewn greater sagacity and industry in discovering their weak sides; always frankly proposing them, as he receiv'd them, to be confirm'd or overthrown, by farther search, and future diligence. And, for proof of this, I appeal to the manner wherein he delivers himself, upon what are, or were esteem'd the most exceptionable things in his writings: the specific virtue of the Peruvian bark, rue-leaved whitlow grass, Ens Veneris, Osteocolla, the Ens Primum of baulm, Butler's stone, the sympathetic powder, the weapon-salve, the alkabest of Paracelsus, the virgula divina, the transmutation of metals, projection, or the philosopher's stone, &c. and desire he may herein be compared with the most approved and judicious authors, who have treated of the virtues of remedies, the secrets in chymistry, and the powers of nature. No doubt Mr. Boyle may appear to give more into the belief of some extraordinary things than the vulgar, or persons unacquainted with experimental philosophy, and the immense powers and strange operations of nature and art; but the question is, whether he has here gone farther than his evidence carried him.

General Preface.

He also relates, upon his own knowledge, many things very astonishing and incredible, to minds unprepared, by philosophy, to entertain them. But Mr. Boyle was so happy, as to have seen, with his own eyes, much more of the powers of nature and art, than can easily be imagin'd. If we consider the numerous phenomena, which, in a very long series of years, spent upon natural inquiries, most of them successful, must have been presented him, by the processes of his laboratory, the experiments of his pneumatic engine, his mechanical, optical, hydrostatical, and all other kinds of trials; the correspondence he happily cultivated with the whole learned world; and particularly with the chymists of all nations; the various secrets he purposely kept to exchange for theirs; and the constant practice he made of doing this; we shall see reason enough to persuade us, that he might well be enabled to deliver things that should sound odd, strange, and shocking to vulgar ears. To render the most innocent fluids poisonous, without altering their colour, taste, smell, or any obvious quality; utterly to erase the hand-writing in a sheet of paper or parchment, without at all unfitting either for ink; to make a base metal pass even upon goldsmiths, for gold; not to mention the more surprising and shocking experiments of the like stamp; are things that can hardly be thought possible, or practicable by the vulgar; yet some chymical philosophers could perform them with ease. But there are some philosophers, and even chymists, who, if you should tell them that Mr. Boyle had a certain liquor, wherewith he cou'd convert gold into silver; they would beg to be excused believing so strange a thing: and why? but because they never saw the like perform'd; and had tied themselves down to a narrow strait-laced philosophy, that would not suffer them to look abroad, into what nature and art can produce. But if Mr. Boyle has actually done the thing; and others, men of veracity, have assured him they had done it too; is he credulous for believing it? Those rather were so, who, without sufficient evidence, rashly concluded the thing impracticable.

Since Mr. Boyle assures us, and gives us sufficient grounds to believe, that he has render'd silver, gold, fixed alkalies, &c. volatile; converted acids into alkalies; produced light from a de-

General Preface.

xi

despicable dark substance; immediately restored fetid, and corrupted water, by precipitating from it a substance not fetid; dissolved the hardest bodies by innocent and potable liquors, without heat; produced cold by a mixture of warm bodies; heat by a mixture of cold ones; warm'd cold liquors by ice; instantly froze spirit of wine; converted that spirit into water; water and fixed alkalies into earth; and perform'd numberless other surprizing things, that appear as so many contradictions among the unskilful; may he not, with good reason, speak of them as feasible, and proper to be tried by others? or may he not, upon the strength of human testimony; upon the relation of his friends and acquaintance, believe that other men have done the same, or even greater things than these; tho' himself was not an eye witness of them? If, after having made his liquid phosphorus in England, he should be assured that another chymist had made a solid one in Germany; if, after having invented his air-pump, he should have heard, that many unsuspected discoveries were made by means of it; if having converted gold into silver, eye-witnesses should inform him, that silver has been converted into gold; or if having himself prepared a menstruum, almost as strange as the alkabest; could he be reproached with credulity, for believing, that Paracelsus, or Helmont, might possibly possess it in greater perfection; or that the other things were done by others? This, surely, is not unphilosophical, or irrational. Mr. Boyle was too wise to set any bounds to nature; he was not forward to say, that every strange thing must needs be impossible, because he saw strange things every day; tho' he always acknowledges, and it was a common saying with him, that "those who had seen them, might better believe them, than those who had not." He modestly thought, that all we have to do is, to keep our eyes open, and expect what nature and art will, upon due application, perform. He was well aware, that there are powerful agents in the world, whose laws, and manner of acting, we want to be acquainted with. A man of a different cast, or an ignorant Indian, who had never look'd abroad, and seen the common phenomena, would scarce credit the most faithful and exact relation that could possibly be made him, of the properties

General Preface.

and effects of the load-stone, or of gun-powder, by persons of the greatest veracity. But his ignorance alone is the cause of this incredulity. Propose the same things to a man who never heard of gun-powder, or the loadstone, but is otherwise a general philosopher; and he will readily and thankfully yield his assent, and solicit you to shew him the experiments. This we may certainly depend upon, what Mr. Boyle delivers as an experiment or observation of his own, is related in the precise manner wherein it appear'd to him: no one ever yet deny'd, that he was a man of punctual veracity. And what he delivers as received from other hands, if it be any thing extraordinary, the reader will find, that he does it with a manifest diffidence, and in a quite different manner from that wherein he gives us facts upon his own knowledge; and never entertains it for truth, without producing something analogous or parallel, to countenance it, from his own observations or experience; always reserving to himself the full liberty of believing no more than he sees reason for. And what can a man do more than this, to avoid the imputation of credulity? On the contrary, do not those who, without evidence, and merely from common report, believe Mr. Boyle to have been credulous, give us a remarkable instance of their own credulity? Wherever our author believes more than other men, it is because he had more reason for it than they. 'Tis the general way, indeed, when a strange thing is related, either positively to deny it as impossible, or directly to entertain it as a truth. This is making short work of it. But Mr. Boyle possessed, in a great degree, that noble faculty of suspending his judgment; till, by all the inquiries he could any way make, he received fuller information; and then the thing he found wou'd determine it self.

Thus much, I hope, may justify my saying, 'tis with exquisite judgment that Mr. Boyle conducts his reader thro' all the regions of nature. I presume, it will appear too, that beginning at the fundamental principles of things, he at length leaves him qualified to pursue any inquiry he shall think fit to go upon.

'Tis impossible in a small compass, to particularize all the discoveries which Mr. Boyle has made in the several branches of natural knowledge; nothing less than the abridgment it self
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General Preface.

xiii

can suffice for this purpose: and there the reader will find himself enrich'd with new notions, new sensations, new reflections; not a product of nature, not a single plant, animal or mineral, no not a part of them, but may contribute to our delight, instruction, and advantage.

Mr. Boyle is altogether taken up with the objects around us, and of which we are, or may be put in possession; tho' we remain ignorant of their properties, virtues, and uses, till he calls them out, sets them before us, and surprizes with a sight of our own ignorance of things so near us, so momentous in themselves, and so necessary to our well being, and the true enjoyment of life. There is no profession or condition of men, but may be benefited by the discoveries of our author. As he had a wonderful comprehensive genius himself, he has improved every part of natural knowledge; and the world is more obliged to this single man, than to a thousand vulgar philosophers taken together. 'Tis certain, that he laid the foundations of almost all the improvements which have been made since his time, in natural philosophy; and actually himself perform'd abundance of those very things, and, perhaps, in a much better manner too, whereby several famous men have gain'd a reputation, in putting them off for their own discoveries. A very fine collection of useful knowledge, publish'd as the works of a foreign society, bears a remarkable testimony to this truth. The mechanic, the merchant, the scholar, the gentleman, all are benefited by Mr. Boyle. He shews us trades in a new light, and makes them, what they really are, a part of natural philosophy; and, considering them accordingly, reveals some of their mysteries; all along advancing proper means to encourage, promote, and multiply the arts themselves. The goldsmith, the lapidary, the jeweller, the refiner, the stone-cutter, the dyer, the glass-maker, artizans of all kinds, will from him receive the best informations, as to the working, managing, and employing to advantage their various commodities, materials, engines, and instruments. The husbandman and the dicer are here instructed in their arts; and the mineralist, the miner, and assayer, to find and separate their ore to the greatest profit; to increase the quantity, to meliorate, improve, and enrich their metals; to purify and
fine

General Preface.

fine them, and accurately to distinguish the genuine and pure, from the adulterate, base, or counterfeit. The architect and builder are shown how to chuse the best materials for their several purposes; the painter to make, to mix, and improve his colours: and no part of mankind is neglected by Mr. Boyle. But he shows a more particular regard to those professions, wherein the health of the species is nearly concern'd. The physician, the anatomist, the apothecary, and the chymist, are most highly indebted to Mr. Boyle. He has consider'd and improv'd the art of medicine in all its branches. We owe to him the best ways we have of distinguishing genuine drugs from adulterate; the discovery and preparation of several valuable medicines; with the manner of applying abundance to good advantage. He has shew'd us the way wherein specifics may act; how to judge of the wholesomeness and unwholesomeness of the air, of water, and of places; and how to examine, and make choice of mineral springs. In a word, there is scarce an art, or natural production known, but he makes some useful discovery or improvement in it.

Then for his temper, it was most open, candid, generous, and communicative. He endeavours to make all the things he treats of, plain, easy, and familiar. There is no deep knowledge in mathematics, or algebra, previously requisite to understand him fully: no tedious systems need be read, to prepare us for reaping all the advantages of our author's philosophy. He brings us at an easy rate acquainted with the most useful things in nature; and this all the world agrees to be the highest excellence in a philosophical writer. The memory of Mr. Boyle will be dear to posterity, whilst that of mystical and enigmatical writers, such as study to make things difficult, and envy mankind their knowledge, shall meet with the disregard and contempt they deserve. What principally recommends our author, and distinguishes him from the vulgar herds of chymists, naturalists, and philosophers, is this humane temper, this open, candid, generous, and beneficent disposition. He was at immense pains and charge, in making his inquiries; he spared no time, no money, no diligence, in pursuing discoveries for the public advantage; without any sordid view to increase his own fortune, which he
hap-

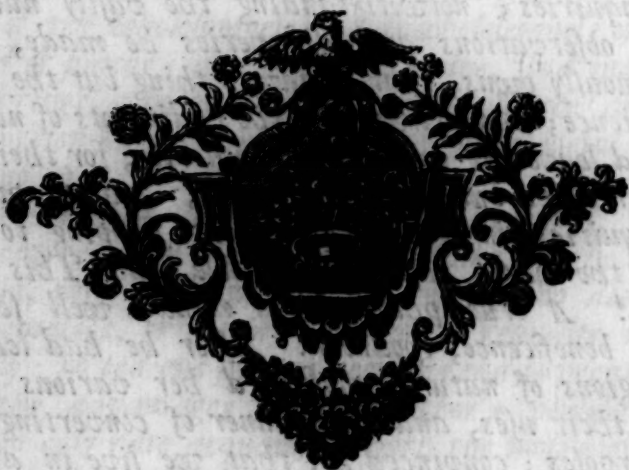
General Preface.

XV

*happily thought sufficient of it self. His beneficent and public spirit made the world a generous present of all the fruits of his labours, without the least expectation of reward from them. His soul was as great and noble, as his genius was comprehensive, or his invention fruitful. And what shews him in the most amiable point of light, he was far above the selfish pleasure, of being admired for a genius, or raising a reputation by his discoveries. Tho' he wanted no capacity, or abilities, to have work'd up a glorious system, and erected a more pompous, ostentatious, and, perhaps, a more durable structure of natural or chymical philosophy, than had ever appear'd in the world before; he nobly despis'd this poor satisfaction, and mean gratification; telling us plainly and expressly, that, notwithstanding all he had done, all the labour, pains, and expence, bestow'd in a life of natural inquiries; notwithstanding the vastly numerous and important observations and discoveries he made, he frankly and ingenuously owns, that he saw nothing but the first dawning of science; has drawn only the rudiments of natural knowledge; and leaves it in charge to posterity, for their own sakes, to consider him but as a beginner; and to pursue philosophical inquiries in general, without stopping to raise petty systems by the way. Here was a noble soul! This the desirable character! A true philosophical mind, well season'd with humanity, beneficence, goodness! After he had lead us thro' all the regions of nature; consider'd her various productions; shew'd us their uses, and the manner of converting them to our several purposes; convinced us, that we live in a world most wisely contrived, wherein numberless grand designs are at once carried on with unceasing variety; and manifested that all the beings, and all the bodies we know, jointly conspire, as one whole, in bringing about the great ends of nature; he bids us not stop here, but leaves us full of assurance, that the farther we inquire into the works of the universal architect, the more beauty and harmony, the greater use and satisfaction we shall find among them; and this as long as the frame of the world endures. These noble, manly, and generous notions, are what the reader will find inculcated thro' the
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General Preface.

philosophical writings of Mr. Boyle; whose principal aim, and great delight it was, to benefit mankind by them: and this valuable end I shall count it happy, in any degree to promote, by having fitted and prepared them for the ready and commodious perusal of every reader.



A Preliminary

DISCOURSE,

Extracted from

Particular Pieces of Mr. *BOYLE*;

And Serving as a GENERAL PREFACE to his
PHILOSOPHICAL WRITINGS.

TIS, in my opinion, one of the principal impediments to the advancement of natural philosophy, that men have been so forward to write systems of it. When an author, after having cultivated only a particular branch of physics, sets himself down to give a complete body of them, he finds himself, by the nature of his undertaking, and the laws of method, engaged to write of many things wherewith he is unacquainted; whence he is reduced, either idly to repeat what, perhaps, has already been impertinently deliver'd on the subject; or to say any thing of it, to avoid saying nothing. But the specious and promising titles of these system-writers are apt to persuade the unwary, that all the parts of natural philosophy have already been sufficiently explain'd; and, consequently, that it were needless for them to be at any farther expence and trouble in making enquiries into nature; the business being done to their hands.

And no less prejudicial is this way of writing to the reputation of the author himself. For it frequently happens, that when a writer, to vent a few particular notions, or discoveries of his own, presumes to give a body of philosophy, that part which is truly his, tho' excellent in its kind, seems either lost in the crowd of things he has borrowed from others, and so comes to be overlook'd by the reader; or else the tedious and ungrateful repetition of things, several times read in other authors, occasions the whole book to be thrown aside, as a rhapsody of trite and vulgar notions, unworthy the perusal: whence, what wou'd

have made an excellent and substantial essay, passes but for a dull and empty book.

The worst inconvenience is still behind; for whilst this vanity of writing, either systems, or nothing, is indulged, many useful notions or experiments, are by sober and modest men suppress'd; because their judgment and integrity forbid them to teach more than they understand, or to assert more than they can prove: whence, of consequence, this pernicious custom prevents them from publishing their thoughts and observations, till they are numerous enough to swell a system. So that I am afraid, the system-writers have hinder'd the world from much more useful compositions than their own. For there are very few men, if any, enrich'd with a sufficient stock of experiments and observations, to make out clearly and solidly, I will not say all the phenomena of nature, but of any subordinate branch of physics. And those who are diligent and judicious enough, thoroughly to study any part of philosophy, will, from the difficulties and uncertainties they find therein, be the most backward of all men to write systems.

And what we have thus said of universal system-writers, is proportionably applicable to those who pretend to give us complete accounts of chymistry, or any other considerable and comprehensive part of natural philosophy. Tho' I must own, that from these attempts, which are much less difficult than the former, mankind has received considerable advantages; how short soever the authors may have fallen of their pompous titles. Nor would I discourage the publication of a system of philosophy, or any part of it, from time to time, by some very intelligent writer, taken from the best authors and observations then extant; for such a work may be serviceable in many respects, if it contain any considerable improvements in knowledge, more than the last work of the same nature. But, for my own part, I am very sensible of the want of a sufficient stock of experiments and observations, to write systematically. And, indeed, I cannot but impute many of the deficiencies in the reasonings of *Aristotle*, and other celebrated philosophers, to their having too hastily, and without due observation, or a sufficient number of experiments, presumed to deliver axioms, and establish principles. For the theories that are built but upon a few obvious experiments, are very liable to be overthrown by a fuller enquiry into nature. And, truly, if men were willing to regard the advancement of philosophy, more than their own reputations, it were easy to make them sensible, that one of the most considerable services they could do the world is, to set themselves diligently to make experiments, and collect observations, without attempting to establish theories upon them, before they have taken notice of all the phenomena that are to be solved. I wou'd not, however, debar men from reasoning upon experiments, and endeavouring to discern, as early as possible, the agreements, differences, and tendencies of things; such an absolute suspension of the rational faculty is, perhaps, impossible; at least, 'twou'd be

be exceeding irksome. It sometimes conduces to the discovery of truth, to frame an hypothesis to solve a difficulty; for the understanding may be instructed, even by its own errors. What I wish for, with regard to systems, is, that men would always procure a number of experiments proportionable to the extensiveness of the theory to be built upon them*: and, in the next place, that such kind of superstructures shou'd be look'd upon only as temporary, and preferable, indeed, to others, as being the least imperfect; yet not entirely to be acquiesced in, as incapable of farther improvements and useful alterations.

Thus much for the inconveniencies of the systematical way of writing; whereto that which we, in imitation of the *French*, call essay, seems directly opposite.

'Tis, certainly, a great convenience in this latter manner of writing, that the reader need not be tired with tedious repetitions of what others have said; and that the author, being at liberty to break off when he pleases, is not obliged to endeavour to teach what he does not understand; or to write of any subject, unless he can do it well. And if such essays be, as they ought, but competently stock'd with experiments, 'tis the reader's own fault if he does not improve by them†. When an author acquaints me only with his own thoughts, or conjectures, if he mistakes in his reasoning, I am in some danger of erring with him; at least, I may lose all the time and pains I bestow upon him: but if a writer endeavours, by enriching his discourse with new and real observations or experiments, to credit his doctrine; let his private opinion be ever so erroneous, yet his experiments being true, I may make my own use of them; and even plead them against his opinion: so that such a writer will certainly teach me useful truths, and cannot easily lead me into error.

From hence, then, appears the great usefulness of experimental essays in general.

As for the manner wherein my own are written, I have, thro' the whole, aimed at a plain philosophical style, and clear significant expressions, rather than such as are ornamental. And, certainly, where our design is to inform, not to delight, or persuade, perspicuity is one of the best qualifications in style; and to affect rhetorical flourishes in

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* No philosopher appears to have observed this rule more exactly than the incomparable Sir *Isaac Newton*: and, accordingly, as his theory is very extensive, so are his experiments numerous; but being always wonderfully simple, and well chosen, a few of them compared together, soon lead to greater discoveries, than many times their number wou'd, when contrived by vulgar heads, and executed by vulgar hands. Such a sagacity in finding out the leading experiments

of an enquiry, and executing of them in the shortest ways, is the highest qualification in an experimental philosopher. Mr. *Boyle* had a great talent in thus contriving experiments, and bringing things to the trial; especially when he could be accommodated with the proper engines and instruments.

† All Mr. *Boyle*'s philosophical pieces, are properly essays, well stock'd with experiments and observations.

Preliminary Discourse.

setting down an experiment, or in explaining some abstruse phenomenon, were as improper as to paint the eye-glass of a telescope, where clearness alone is the thing required. 'Twas not an unpolish'd philosopher, but the prince of orators, *Cicero* himself, who said, "whatsoever is clearly express'd upon a good subject, appears to me to be excellently spoken; to affect elegance in such a case were childish; to speak plainly and intelligibly here, is what a wise and a learned man wou'd choose."

I expect it will be observed to my disadvantage, that I speak doubtfully upon most occasions; which seems to argue a diffidence of the opinions I incline to: but having met with many things, for which I cou'd assign no probable cause, and with some, for which many very different ones might be alledg'd; I dare speak positively and confidently of very few things, except of matters of fact. 'Tis not that I condemn the practice of bolder men, who attempt to solve the most abstruse phenomena of nature; I admire them, where their endeavours succeed; and tho' they fail, applaud them: but a man should know his own abilities, and not imitate all he thinks fit to praise. 'Tis, I am sensible, the ready road to fame, to solve phenomena, and propagate opinions; but by the way of writing to which I have condemn'd my self, I can hope for little better than to pass for a drudge, of greater industry than reason; and fit only to collect experiments, for more philosophical heads to make use of and explain. And I am content, provided experimental knowledge be really promoted, to contribute in the meanest way to advance it; and had rather be an under-builder, and even dig in the quarry for materials towards so useful a structure, than not assist in erecting it. But, to say the truth, I have not been wholly wanting in framing notions, and devising hypotheses, free from the deficiencies and errors I observed in those of other men; tho' with this success, that I have hitherto commonly found what pleased me for a while, as squaring with the observations on which my notions were grounded, was soon after contradicted, or disgraced, by some new experiment or observation, either before unknown, or unthought of. And thus it has fared with many eminent writers, who have taken upon them to deliver the causes of things, and explain the mysteries of nature; for their doctrines, after having, for a short time, been applauded and admired, have been afterwards confuted by the discovery of new phenomena.

Notwithstanding all this, I have, on some occasions, ventured to deliver my opinion; because I rather chose to run the hazard of being sometimes mistaken, than not afford my reader the best assistance I could towards the discovery of truth. And because in my solutions, and explanations of natural effects, I have not always an immediate recourse to the magnitude, figure, and motion of atoms, or the component particles of bodies, 'tis proper I should give my reason for this procedure. For many men of learning, and especially physicians, are in

in danger of being despised, on account of an opinion taken up from the misapplied doctrine of some eminent *Atomists*, as if no theory in natural philosophy cou'd be rational, where any other causes of things are assign'd, than atoms and their properties. But, in general, to assign a reason of an effect, is to deduce it from some other thing in nature, more known than it self; and, consequently, there may be several degrees of explaining the same thing. For tho' such solutions are the most satisfactory to the understanding, which shew how the effect is produced by the more primitive and general properties of matter; yet those accounts are not to be despised, that are taken from the obvious and familiar properties, or states of bodies; tho' these themselves, probably, depend on the more universal. In the search after natural causes, every new measure of discovery both instructs and gratifies the mind; tho' the nearer the discovered causes approach to the highest in the scale or series, the more is the understanding gratified and instructed*. 'Twou'd, therefore, be highly useful, if some mathematical genius were employ'd, in deducing the principal modes or qualities of matter, such as heat, cold, &c. with the states and conditions of it, as fluidity, firmness, &c. from the primitive and simple properties thereof, as figure, motion, &c. In the mean time, we shou'd not reject all those accounts of particular effects, which are not immediately deduced from the primary properties; but from the less universal qualities of things, as cold, heat, weight, &c. And this too wou'd much shorten the explanation of particular phenomena, which, otherwise, must be excessively tedious. Thus, he easily assigns a tolerable reason why all metals, except gold, swim upon quick-silver, who teaches, that those metals are lighter than quick-silver, but gold heavier; tho' he does not deduce the phenomena from atoms, nor say why gold is heavier, or assign the general cause of gravity. Thus a physician will tell you, that rhubarb cures a looseness, by a laxative virtue, whereby it carries off the cause, and an astringent property, whereby it afterwards stops the flux: but, if you ask him, why rhubarb purges, he will hardly give you a satisfactory answer. Yet a skilful physician would think himself injured, if the reasons he renders of things in his own profession, were denied to be reasons, because not built upon atomical principles. And, indeed, there are often so many subordinate causes

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* 'Tis unphilosophical to resolve effects into the original cause of all things, the supreme Being, without an absolute necessity. Indeed, by discovering more intermediate causes, we only lengthen the chain, and must end in the author of nature at last; but it is the business of philosophy, to discover all these links; and to shew, if possible, how the last is connected with the rest. Many philosophers tell us, that gravity is, doubtless,

immechanical, and must be immediately resolved into the will of God; yet Sir *Isaac Newton*, with great sagacity, has nobly attempted to give a mechanical account of it. The practice, therefore, of this illustrious author, as well as of Mr. *Boyle*, shews, that philosophers shou'd not be too hasty in solving phenomena from the will of the Creator; because it tends to stop the progress and advancement of natural knowledge.

Preliminary Discourse.

of things, that a large field is left wherein to exercise human industry, in solidly deducing the properties of bodies, from more general and familiar qualities; and, also, intermediate causes from one another. And we should the more readily allow of such causes as these, because there are some things, for which no physical causes at all are assignable; as of the origin of local motion, for instance.

There are two very different ends in studying natural philosophy; to please a man's self in the discovery of the causes of known phenomena, and to be able to produce new ones. Now, as the atomical principles are likely to give most satisfaction in the knowledge of causes; so philosophy may be pursued with great success and delight, by collecting and making a variety of experiments and observations. When an engineer employs gun-powder, 'tis not necessary he should know the ingredients whereof it consists, or the proportions wherein they are mixed; the common notion of this powder, will enable him to perform surprizing things with it. And a physician, who has observ'd the medicinal virtues of *Venice-treacle*, may, tho' he know not the names or nature of the numerous drugs whereof 'tis composed, cure several diseases with it. 'Tis, indeed, an advantage, as well as a satisfaction, to know, in general, how the qualities of things are deducible from the primitive properties of the smallest parts of matter; yet if we are only acquainted with the qualities of the bodies they compose, and how these are dispos'd to operate upon other bodies, and to be wrought upon by them, we may, without ascending to the top of the series of causes, perform things of great moment. Artificers, who never dream'd of the *Epicurean* philosophy, have accommodated mankind with a multitude of useful inventions. But to return.

I have purposely refrain'd from swelling my discourses, with solemn and elaborate confutations of other mens opinions, except in some few particular cases, where I thought they might prove great impediments to the advancement of experimental knowledge: and even such opinions I have been cautious of opposing, unless with experimental objections. For I design not to engage with any sect of philosophers. I wou'd endeavour to destroy the groundless structure of opinions, as fantastical objects are abolished, by letting in more light upon them. And experience shews, that many plausible and radicated opinions, have been thus demolished. Indeed, such opinions will vanish of themselves, tho' no body shou'd expressly write against them.

'Tis, also, contrary to my inclination, to transcribe passages out of authors, which commonly add much more of bulk, than of worth, to a book. But where particulars are of that nature, or moment, as to require proof or illustration, I have sometimes been obliged to comply with this custom; tho' I always appeal to other writers, not as judges, but witnesses.

I must here apologize for one thing, that is very contrary to my nature, the concealing some particulars in my writings. But these are such

such as I either had upon condition of secrecy; such as are made a pecuniary advantage of by some particular persons; such as I purposely keep by me, to exchange for the secrets of others; or, lastly, such as are easily capable of being converted to ill uses. The reader, therefore, must not think himself unkindly dealt with, if, upon these considerations, some processes and receipts are kept from him. The number of these, however, is but small; and he has ample amends made him by a large collection of others freely presented him.

To excuse the prolixity used in setting down many of my experiments, I might represent, that most of them being wholly new, required to be circumstantially deliver'd, to gain them a thorough assent; but the principal reason of this was, my designing them to serve as full and faithful records of the things themselves; whereby they might save others the trouble or expence of repeating them.

If any one shall think, that in my discourses I reveal too much of the secrets and mysteries of trades, I wou'd have him consider, that my design being to instruct, and, sometimes, to convince my reader, I was frequently driven to make use of such sensible and obvious experiments, as easily gain credit, or may be seen with little trouble: and because I write for philosophers, not to instruct men how to raise estates, I seldom divulge more than an experiment or two in any particular trade; which is far from enabling a person to practise the whole of that trade. But such benefits may accrue to trades from a philosophical consideration of them, that the artist might well excuse the being made free with upon such an occasion. The inventions of philosophical heads set great numbers of mechanical hands to work; and furnish them with means of procuring not only a subsistence, but estates too. The truth is, I have been the more particular upon this subject, in hopes of removing philosophy from the shops into the schools; which might prove as serviceable to trades themselves, as to the history of arts and nature. And I shall not think my labour lost in recording what may to some appear trifling experiments, if by striking in with the humour or genius of my reader, any one of them shall give him a relish for experimental knowledge: for the pleasure, variety, usefulness, and other endearing qualities of that pursuit, must surely invite him to a farther progress, whereby many great advantages may be derived to the world. Natural philosophy is not that barren thing it has been long accounted: I only wish, that I cou'd rouse up the generality of inquisitive persons, and excite the curiosity of mankind to the making of experiments; from which alone the greatest advancement of useful knowledge is to be expected. To encourage and facilitate this practice, give me leave here to propose a general method of drawing up the proper heads of enquiry for philosophical subjects; according to the model whereof my own searches into nature were generally directed.

Preliminary Discourse.

In the first place, I propose to my self three sorts of heads, whereto all the particulars which occur, belonging to the history of a subject, whether it be a body, a quality, an operation, or a process, may conveniently be referr'd. These distinct sets or topics of enquiry, I call orders, ranks, or classes. And finding that things of different natures were referable to each set, for instance, queries, propositions, &c. I chose to take in all these kinds of topics, or articles of enquiry, under the general and comprehensive name of titles. The first order of these titles I made to consist of such as readily occur'd, upon the primary deliberate view, or general survey of the subject. For a man can hardly be so clear-sighted, or so happy, as at a first attempt to light upon such short, direct, and advantageous methods of digesting, and delivering his discoveries, as might afterwards be afforded him by a thorough inquiry, and farther informations. It may, therefore, suffice for the first, that the mind takes a general survey of the subject, views it on every side, and observes the different prospects it affords. There is no need of being very scrupulous in enumerating and ranging the particulars referable to this class; but only to order it so, that the titles may be sufficiently various and comprehensive, rather than exactly methodical, or accommodated to any particular hypothesis. And because, even at the first deliberate view, some of these titles may appear so considerable and fruitful, as to deserve that several subordinate and more particular topics be referr'd to them; I call the capital titles, or those of this first class primary, and the subordinate secondary titles.

Now, when by reading, conference, meditation, and the experiments suggested by the heads of the first class, we have receiv'd the fullest information we can procure, of every thing that relates to the subject; we may then proceed to form another set of titles, to be call'd the second, or, if no other interpose, the last class; which, if we have been diligent and successful, will be more copious, and better ranged than the first. For, many things will now, probably, appear to belong to the subject, which before were thought remote from it; or, perhaps, not thought of at all: and farther discoveries will enable us to correct the order of the former titles. Most of the particular heads too will, probably, appear more comprehensive, and of larger extent, than was before imagin'd; so that a particular title may hence be properly branch'd out into several subordinate articles, or secondary titles; one whereof alone will, perhaps, comprize as many experiments, or observations, as at first seem'd to belong to the primary, or more general title it self. And from the materials thus orderly drawn together, under this last class, with the requisite changes in point of method, connexion, transitions, and additions, may be form'd the beginning of a natural history of the subject whereto they bear relation. For, even after all this is done, the history will, in all probability, be only begun, not compleated; the nature of things, and the industry of skilful men being so fertile, that the history will, doubtless, be increased,

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corrected, and improved from time to time; but never, I fear, in many ages, arrive at absolute perfection.

When the subject to be treated, is either very comprehensive, or very difficult; as those of animal generation, magnetism, fermentation, gravity, &c. it will be useful, if not necessary, to interpose between the titles of the last, and of the first class, a set that may be called of the middle order; for the framing whereof the nature of the subject must be narrowly scann'd, surveyed afresh, and carefully compared with the several particulars, obtain'd and disposed under the titles of the first class. Hence many new hints, and heads of inquiry will, in all likelihood, be suggested; which, added to the former, may deserve to have a new class framed for them, consisting of articles more copious and various than the first; and fit to be ranged in a different order. These several titles are to be touch'd and fill'd up, after the same manner that the *Israelites* gradually acquired a knowledge of the fruitful land of *Canaan*, before they possess'd it: at their first entrance, the spies took a transient view of the country, and brought back but an inaccurate account thereof, with a little of the more remarkable fruit it afforded; but upon a second expedition, taking pains to gain fuller instructions, they return'd able to answer many particular articles of inquiry: and this latter industry wou'd enable them to give a far more distinct and satisfactory chorography, or survey of the country, than they cou'd have furnish'd out before their second expedition.

Lastly, as 'tis not to be expected, that the titles, whether primary or secondary, of a natural history, shou'd need no enlargement, or reformation from second thoughts, and a more comprehensive practical knowledge of the subject; I always thought it necessary to annex to the first edition, if I may so call it, of my titles, an appendix, consisting of things omitted, and things to be added; the former whereof are properly referable to some of the titles already enumerated, and only thro' haste, or oversight, had not their places assign'd them; but the latter were to receive such new particulars, as shou'd be suggested by farther advancements, after the history was written; whether they directly belong'd to any of the preceding titles, or might, only in a general way, contribute to the knowledge or illustration of the subject.

To proceed, I must observe, with regard to the mechanical contrivances employ'd in the execution of my experiments; that tho', in general, they answer'd my purpose, yet much more artificial instruments may be invented. But being frequently obliged to make my experiments at a distance from *London*, I was glad to put in practice the best methods I cou'd any way devise, where all desirable conveniencies were not to be had. Indeed it has been no small hindrance to the advancement of natural philosophy, that some nice critics are so rigid in exacting the very best contrivances, in those who publish their experiments; for every philosopher has not a mechanical head. And he

may well be esteem'd a benefactor to natural philosophy, who barely contrives experiments in theory, or proposes practicable ways of bringing things to a trial: for the increase of knowledge is the product of the things themselves that are discover'd; whatever means or instruments are used in the discovery of them. 'Tis true, in curious and extraordinary cases, perfection in the contrivance may be desirable, useful, or even necessary; yet in many others, where only the production of a new phenomenon is the thing intended, he contributes to the history of nature, who really performs the substantial part of a discovery, tho' it be not in the most easy, most perfect, and most compendious method imaginable. *Archimedes* himself, if history says true of him, went a much more laborious and inaccurate way to assign the proportions of gold and silver, in a mixture of those two metals, than is taught us by the modern hydrostatics; tho' this, perhaps, wou'd have remain'd undiscover'd, but for the hint afforded by his method of procedure.

To prevent, as much as possible, the necessity of cuts, or the figures of the instruments which I employ'd in my experiments, I have made the relations and descriptions of them full and plain; yet, lest my own habit of devising various trials, and the frequency of seeing them put in practice, might have led me to imagine things more intelligible than the generality of readers wou'd find them, I advis'd with some proper persons, as to the experiments necessary to be illustrated with schemes or figures; which are so contriv'd, as generally, by inspection, to express and clearly represent the things they were design'd to shew; without referring, by letters, to the particular parts whereof they consist.

There is another particular, which must not be pass'd over in silence, the frequent repetitions to be met with in my writings. Having often been oblig'd to write at a great distance, as well of place, as of time, from the books that I had formerly publish'd; and so wanting the opportunity of consulting them; the mention of things already there deliver'd, was render'd sometimes unavoidable: tho' I hope these generally appear on such different occasions, serve such different purposes, and are attended with such additional circumstances, that the reader will not be disgust'd to meet with the same thought in different parts of my works.

Give me leave, in the last place, to explain my self, as to the opinion which I may seem to have entertain'd of chymistry; and as to the use I have made of it in my philosophical inquiries.

After having gone thro' the common operations of that art, and coming seriously to reflect upon them, I thought it pity that instruments, which might prove so serviceable to natural philosophy, shou'd be so little employ'd to advance it. I saw that several chymists had, by a laudable diligence, obtain'd various productions, and hit upon

upon many more phenomena, considerable in their kind, than could well be expected from their narrow principles; but finding the generality of those addicted to chymistry, to have had scarce any view, but to the preparation of medicines, or the improving of metals, I was tempted to consider the art, not as a physician, or an alchymist, but a philosopher. And, with this view, I once drew up a scheme for a chymical philosophy*; which I shou'd be glad that any experiments or observations of mine might any way contribute to complete.

There are many men, who, having no knowledge of chymistry but by report, entertain a very disadvantageous opinion both of the art, and those who profess it: and because it has been too often practised by illiterate, arrogant impostures, they will scarce allow a philosopher to understand or study it. But, surely, without seeking after the grand elixir, this art may greatly promote our knowledge of the works of nature. 'Tis certain, that by means of it, some meliorations of metalline and mineral bodies may be made, useful medicines prepared, and various productions serviceable in particular trades, and several occurrences of human life, obtain'd. And tho' this alone suffices to shew, that a man might study chymistry to advantage; yet, as I before intimated, I had a larger view in cultivating it; and have attempted no less than the advancement of natural philosophy, by means thereof. And, I hope, I shall have done no unacceptable service to the common-wealth of learning, if, by my acquaintance with this art, I beget a good understanding betwixt the chymists, and the mechanical philosophers, who certainly have hitherto been too great strangers to each others discoveries.

I cou'd, indeed, have ordinarily employ'd more considerable chymical experiments in my essays, but thought fit to give the preference to such as were simple, short, and easy, and such as might be made at a small expence; because these I judged the fittest foundations for a philosophical theory. And the gratification of the chymist was not here so much my design, as to oblige the philosopher.

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* A large part of that collection of experiments, which were made with a view to the chymical philosophy here mention'd, Mr. Boyle afterwards thought fit to employ in giving the mechanical origin of qualities in bodies, and clearing up other philosophical difficulties; whence tho' the major part of his essays have not the form of chymical ones, they are no other at the bottom. Nor does there seem to be any better method in nature, for improving natural philosophy, than that which builds

upon genuine chymistry. A rational, and experimental essay of chymical philosophy, which might be drawn from Mr. Boyle's discoveries, and some others that have been made since his time, wou'd open a surprizing scene in the works of nature; and prove infinitely more entertaining to the mind, and advantageous to human life, than a stranger to the various operations, numerous productions, and astonishing effects of philosophical chymistry, can possibly imagine.

But, as I may my self seem an enemy to the chymists, by opposing some of their tenets, I desire it shou'd be observ'd, that I have a very different esteem for the notional, and for the practical part of chymistry. For I have been obliged to call in question many of their tenets, not only as a philosopher, but also as a chymist; because they appear'd disagreeable to the very foundations of philosophy, and genuine chymistry it self. Such an one, for instance, is the hypothesis of the three principles in natural bodies. But as for the chymical operations, and especially those highly valuable ones, digestion and cohobation, I take them to be excellent tools in the hands of a natural philosopher, who may apply them to many different, and, perhaps, nobler uses, than those whereto they are generally confined in laboratories; and by their means discover, imitate, correct, and, in some cases, even excel nature. I, likewise, distinguish betwixt the vulgar chymist, and the chymical philosopher. For, we are told, there is in the world a set of men, of a much higher order than those who give us courses of chymistry, or other books of that nature, able to transmute baser metals into perfect ones, and to do some other things, that the generality of chymists confess to be extremely difficult, and some of them think impossible. What I have received from credible eye-witnesses, and, perhaps, some more immediate arguments, strongly incline me to think there may have been, and yet are, some such men. And, whatever be thought of the philosopher's stone, I confess my self convinced, by what I have seen, that there are in the world as difficult *Arcana*, as many of those which have been derided for chymical non-entities. And if such men there are, I cannot but fancy them possess'd of some exceeding powerful menstrua, whereby they may produce such alterations in bodies, as we have no examples of. Thus much will serve to shew the chymists, that I am no enemy to their art; and, indeed, I think it eminently conducive to extend the empire of mankind, by enlarging our views, and giving us the command of nature. For, as the *Bolanian* stone, unless it were chymically prepared, wou'd never become luminous; so there are many other natural bodies, which never afford light to philosophy, till 'tis struck out to them by chymical operations.

I have nothing more to add, than that I am sensible of the great plainness in my writings, thro' the want of such philological ornaments as learned men bestow upon their productions; but I am not ambitious to appear a man of letters: I cou'd be content the world should think I had scarce looked upon any other book than that of nature*. And, for my own part, I always esteem him the most pro-

* Mr. Boyle appears, by his numerous writings, to have bestow'd so much of his time in natural inquiries, and yet enjoy'd so small a share of health, that, he.

Preliminary Discourse.

xxix

profitable author, who does not endeavour to shew his own learning, but to increase the knowledge of his reader.

he might well have been excused the pains of conversing with authors; but, to our surprize, he was a critic in the learned languages, ready in the use of

several modern ones, and very well versed in all the polite and severer literature, both of the ancients and moderns.



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THE

T H E
C O N T E N T S
O F T H E
F I R S T V O L U M E.

The usefulness of Experimental
Philosophy.

P A R T I.

Shewing

The advantages that accrue from natural philosophy to the mind of man. Page 1

S E C T. I.

1. **O**UR enquiries into nature rewarded by an increase of understanding, and a power to do good. 3
2. Philosophy, whilst it gratifies, does not disgust the mind; but is an employment worthy of it. 4
3. The variety of nature excites our enquiry. 6
4. Philosophy gives us the command of nature. 8

S E C T. II.

5. Whether philosophy leads to Atheism. ib.
6. Two principal designs of God in creating the world. 9.

V O L. I.

7. The attributes of God manifest in his creatures. p. 10

8. His wisdom. 11

9. His goodness. 13

S E C T. III.

10. Whether a stop put to natural enquiries would not deprive God of the glory due to him. 15

S E C T. IV.

11. The Epicurean system, which excludes a Deity, examined. 17

S E C T. V.

12. That a philosopher is by some things persuaded of the existence of God, more than a vulgar mind. 23
13. Philosophy instructs us to admire and celebrate God. 24
14. The fulfilling of prophecies, and working of miracles, demonstrate the being of a God. ib.
15. Philosophy furnishes arguments against atheism. ib.

P A R T

The Contents of the First Volume.

PART II.

Shewing

The usefulness of natural philosophy
to the art of medicine.

SECT. I.

16. That philosophy should be reduced to practice. p. 26
 17. The usefulness of natural philosophy to the physiological part of medicine. ib.
 18. The advantages of comparative anatomy to physic. 27
 19. How to preserve the parts of animal bodies for anatomical purposes. 29

SECT. II.

20. The advantages of natural philosophy to pathology. 31
 21. A knowledge of the properties of bodies, and the phenomena of art and nature, useful to a physician. 31
 22. Stones found in the human bladder, chymically examined. 33
 23. Substances of a mineral nature found in human bodies. 34
 24. Anatomy tends to advance pathology. 35
 25. An hemiplegia occasion'd by a small splinter of a bone pressing upon the Dura mater. 36
 26. Experiments to be made upon brutes, to acquaint us with poisons and their antidotes. 37
 27. Enquiries for the transfusion of the blood of animals. 39

SECT. III.

28. The advantages of natural philosophy to the semeiotical part of medicine. 42
 29. The Peruvian bark recommended for agues. ib.
 30. Too many diseases esteemed incurable. 43

31. The Stone in the bladder and kidneys dissolvable. p. 45

32. Butler's stone. 49

SECT. IV.

33. The advantages of natural philosophy to the hygienal part of physic. 50
 34. The different liquors of different nations. 51
 35. The preservation of aliment. 52
 36. To discover the wholesomeness or unwholesomeness of aliments. 53
 37. Philosophy helps us to judge of the air and water, as to their wholesomeness and unwholesomeness. 54

SECT. V.

38. The usefulness of natural philosophy to the therapeutic part of physic. 54
 39. The neglect of physicians to improve their art. ib.
 40. The usefulness of chymistry to the curative part of physic. 55
 41. To discover whether bezoar be genuine or adulterate. ib.
 42. The chymical analysis of seed-pearl. 58
 43. Mineral earths to be enquired after. ib.
 44. Chymistry may convert noxious medicaments into such as are wholesome. 59
 45. Philosophy may lessen the expence of a cure. 60
 46. Compound medicines consider'd. 61
 47. Many materials used in physic have little virtue, and others neglected that have more. 62
 48. Aurum potable prepared. 63
 49. The Arcanum duplicatum. 64
 50. To save trouble and charges in making chymical preparations. 66
 51. Philosophy may suggest cheaper and better ways than the common, of preparing medicines. 67
 52.

The Contents of the First Volume.

XXXV

- | | | | |
|---|-------|---|--------|
| 52. Surprising things performable by chymistry. | p. 68 | 78. Land improveable by means of chymistry, hydrostatics, &c. | p. 106 |
| 53. Several branches of chymistry improveable. | 70 | 79. Husbandry by medicine, in curing the diseases of cattel. | 109 |
| 54. To improve the means of preserving medicines. | 73 | 80. And by philosophy in curing the diseases of the soil. | 110 |
| 55. Specifics to be endeavour'd after. | ib. | 81. Trades conducing to the delight of mankind, improvable by philosophy. | ib. |
| 56. The vulgar chymistry very incomplete. | 74 | 82. As particularly stone-cutting and smithery. | 111 |
| 57. The search after powerful menstrua recommended. | 76 | 83. Philosophy may introduce new trades. | 112 |
| 58. The body of steel open'd in an extraordinary and uncommon manner. | 77 | 84. Every profession, condition, and person may be benefited by philosophy. | 114 |
| 59. Gold debased by an anti-elixir. | 78 | | |
| 60. That chymistry and philosophy may improve the Methodus medendi. | 79 | | |
| 61. That external remedies should be farther try'd. | 80 | | |
| 62. Diseases cured and caused by frights. | 82 | | |
| 63. Magical cures to be enquired into. | 84 | | |
| 64. To make medicinal experiments upon brutes recommended. | 87 | | |
| 65. Reasons for the use of Specifics. | 89 | | |
| 66. Diseases from imagination. | 90 | | |
| 67. The human body a machine, and acted upon accordingly. | 91 | | |
| 68. Peculiarities of constitution. | 94 | | |
| 69. New remedies to be used, where the old ones have failed. | 96 | | |
| 70. Medicines apparently opposite to a disease, may cure it. | 98 | | |
| 71. Specifics, how they may operate. | 100 | | |
| 72. Physic still improveable by experience. | 101 | | |
| 73. Universal remedies. | 103 | | |

PART III.

Shewing
The advantages of philosophy to human life.

SECT. I.

77. Natural philosophy tends to reform and improve trade. 105

- ### SECT. II.
85. The usefulness of mathematics to philosophy. 117
86. In improving the mind. 118
87. Teaching the figures of bodies. ib.
88. Dividing of weights. 119
89. In framing hypotheses. 120
90. Shewing the true system of the world. ib.
91. The laws of optics. ib.
92. And the doctrine of ratio's. ib.
93. Mathematics may suggest new experiments. 122

SECT. III.

94. Mechanics advantageous to natural philosophy. 123
95. By helping to invent and judge of hypotheses. 124
96. And solve phenomena, as particularly in hydrostatics. ib.
97. Mechanics will assist to multiply experiments. 126
98. The peculiar uses of mechanics in centrobarricks. ib.
99. In the art of diving. 128
100. And the use and application of valves, schemes, models, &c. ib.
101. Mathematics and mechanics too much confin'd in their application. ib.

The Contents of the First Volume.

SECT. IV.

102. Philosophy beneficial by being applied to trades. p. 129
 103. The phenomena of trades, part of natural history; and to be learnt by a philosopher. ib.
 104. Who may thence improve them various ways. 131
 105. And supply the desiderata therein. 136

SECT. V.

106. That such things may be done philosophically, as are usually perform'd by manual operations. 131
 107. Shewn in separating silver from its ore. ib.
 108. In casting the images of things. ib.
 109. The art of etching. 132
 110. In taking altitudes. ib.
 111. In splitting thin plates of metal. 134
 112. Making marbled paper. ib.
 113. Rectifying spirit of wine. ib.
 114. The use of cements. ib.
 115. The obtaining of stone from the quarry. 135
 116. Figuring of glasses, and reducing talc to powder. ib.
 117. Making images in wax. ib.
 118. Graving hand-writing. 136
 119. Taking off written characters, or printed cuts. ib.
 120. And copying at once a whole page of writing. ib.
 121. Instances wherein a knowledge of nature may improve mechanical skill. 137

SECT. VI.

122. Mankind very ignorant in natural things. 138
 123. The works of nature imperfectly consider'd, even in their peculiar qualities. 139
 124. Things have different relations to one another in different places, seasons, &c. 140

125. Bodies must be consider'd mathematically, before their properties can be known. p. 142
 126. Even the most obvious qualities and their uses may be over-look'd. 144
 127. New properties of bodies arise from discovering their new relations. 145
 128. Bodies in conjunction may have new uses. 147
 129. Varying with the different proportions of their ingredients, and ways of management. 149

SECT. VII.

130. Why attempts to repeat experiments fail of success. 153
 131. First, because materials differ in point of genuineness. 153
 132. In their species. 154
 133. And in their preparations. 163
 134. Unregarded circumstances may prevent the success of experiments. 166
 135. Observations contingent as well as experiments. 173

PHYSICS.

The excellence and grounds of the mechanical philosophy.

1. **T**HE mechanical philosophy, what. 187
 2. The principles of the mechanic philosophy, clear and intelligible. ib.
 3. Few. 188
 4. Primary. ib.
 5. Simple. ib.
 6. And extensive. 189

The origin of forms and qualities, serving as an introduction to the mechanical philosophy.

SECT. I.

1. **A**N universal matter. 197
 2. The necessity of motion. ib.
 3.

The Contents of the First Volume.

xxxvii

- | | | | |
|---|--------|---|--------|
| 3. Whence motion proceeds. | p. 197 | 24. The curious figures of salts depend | |
| 4. Matter divisible. | 198 | not upon substantial forms. | p. 241 |
| 5. The notion of real qualities examin'd. | ib. | | |

SECT. V.

- | | | | |
|---|-----|--|-----|
| 6. The relative nature of physical qualities. | 200 | 25. Experiments to shew the origin of forms from the renewing of bodies. | 245 |
| 7. Texture requisite in bodies. | 202 | | |
| 8. Sensible qualities only relative. | ib. | | |
| 9. Form, what. | 206 | | |
| 10. Generation and corruption. | 209 | | |
| 11. The extent of this doctrine. | 213 | | |
| 12. Recapitulation. | 214 | | |

SECT. VI.

- | | |
|---|-----|
| 26. Observations and experiments to shew the origin of forms and qualities. | 247 |
|---|-----|

SECT. VII.

SECT. II.

- | | |
|--|-----|
| 13. The vulgar doctrine of forms consider'd. | 215 |
|--|-----|

SECT. III.

- | | |
|--|-----|
| 14. The doctrine of subordinate forms examined. | 223 |
| 15. The word form, its signification. | 231 |
| 16. The difficulty of deciding the nobleness of forms. | ib. |
| 17. Form attributed to bodies upon account of some one eminent property. | 232 |
| 18. Things depending upon the concurrent action of the parts of one whole. | 233 |
| 19. Subordinate forms to be admitted in some bodies. | ib. |
| 20. The supervention of a new form often accidental. | 234 |
| 21. Besides the specific actions of a body that harbours subordinate forms, there may be several others, wherein some of the parts act according to their particular nature. | 235 |
| 22. That which, in many bodies, is look'd upon as the specific form, is, often, only the most eminent. | 236 |

SECT. IV.

- | | |
|--|-----|
| 23. The production and re-production of forms. | 238 |
|--|-----|

- | | |
|--|-----|
| 27. Experiments to shew the nature of qualities; and first camphire suddenly restored after it seem'd to be destroy'd. | 251 |
|--|-----|

- | | |
|--|-----|
| 28. Changes made by sublimate upon copper. | 252 |
|--|-----|

- | | |
|------------------|-----|
| 29. Upon silver. | 253 |
|------------------|-----|

- | | |
|--------------------|-----|
| 30. And upon gold. | 254 |
|--------------------|-----|

- | | |
|-------------------------------------|-----|
| 31. The process of the Luna cornea. | 255 |
|-------------------------------------|-----|

- | | |
|---|-----|
| 32. Unusual phenomena of a new and surprizing salt. | 256 |
|---|-----|

- | | |
|---|-----|
| 33. A transmutation wrought upon saline bodies supposed almost indistrutable. | 257 |
|---|-----|

- | | |
|---|-----|
| 34. Phenomena in the process of Glauber's sal mirabile. | 259 |
|---|-----|

- | | |
|--|-----|
| 35. The transmutability of metals proved experimentally, by converting gold into silver. | 260 |
|--|-----|

- | | |
|-----------------------------|-----|
| 36. Gold render'd volatile. | 263 |
|-----------------------------|-----|

- | | |
|--|-----|
| 37. Tastes varied by mechanical alterations in bodies. | 264 |
|--|-----|

- | | |
|----------------------------------|-----|
| 38. Water transmuted into earth. | 265 |
|----------------------------------|-----|

- | | |
|--|-----|
| 39. Phenomena from the distillation of oil of vitriol with spirit of wine. | 269 |
|--|-----|

SECT. VIII.

- | | |
|--|-----|
| 40. Remarks upon particular qualities. | 271 |
|--|-----|

SECT. IX.

- | | |
|--|-----|
| 41. Cosmical or systematical qualities introduced. | 282 |
|--|-----|

The Contents of the First Volume.

42. Bodies may not act, unless acted upon by general and unheeded agents. p. 284
43. Subtile bodies in the world ready to insinuate themselves into others. 284
44. Bodies may acquire or lose a fitness to be affected by unheeded agents. 288
45. Cosmical suspicions as to some unobserved laws and orders of nature. 290
7. Intestine motion requisite to fluidity. p. 313
8. The difference between a fluid body and a wetting liquor. ib.
9. Farther proofs of intestine motion in fluids. 314
10. Why different contiguous fluids preserve their surfaces distinct. 316
11. The consistence of bodies upon mixture, hard to determine à priori. 319

A fundamental experiment made with nitre.

1. **T**HE experiment. 297
2. Observations upon making the experiment. 298
3. Deductions from the experiment as to the cause of heat and cold. ib.
4. Sounds. 299
5. Colours. ib.
6. Odours. ib.
7. Tastes. 300
8. Inflammability. ib.
9. Fluidity and firmness. ib.
10. Volatility and fixedness. ib.
11. The notion of menstruums. 301
12. The different virtues of entire bodies, and their separate ingredients. ib.
13. The generation of nitre. 302
14. The forms of bodies. 302
15. Corrosivenes and corrosibility. 303

The origin of fluidity and firmness.

SECT. I.

1. **A** Fluid what. 305
2. The requisites to fluidity, viz. smallness of parts. 306
3. A determinate figure of them. 310
4. Vacuity. ib.
5. Agitation. ib.
6. Experiments to illustrate and confirm the doctrine of fluidity. 312

SECT. II.

12. Firmness what. 319
13. The requisites to firmness, viz. grossness of parts. ib.
14. Rest and cohesion. 320
15. The pressure of the atmosphere one cause of cohesion in bodies. 321
16. Texture another requisite to firmness. 327
17. Several ways of producing this texture. ib.
18. Adventitious particles may conduce to firmness. 331
19. Firmness may be the result of a particular texture. 334
20. The chymical notion of stability, &c. examined. 336
21. Mr. Hobbs's doctrine of fluidity and firmness examined. 346

The mechanical origin and production of volatility and fixedness.

SECT. I.

1. **T**HE qualities which render a body volatile are chiefly four. 369
2. Smallness of parts. ib.
3. Rarity or lightness. ib.
4. Aptness to motion. 370
5. And a loose texture or weak cohesion. ib.
- 6.

The Contents of the First Volume.

xxxix

6. Five ways of introducing volatility into bodies. p. 370
7. The first way. ib.
8. The second way. 371
9. The third way. 373
10. How the particles of an added ingredient may contribute to raise those of another body. ib.
11. Salt of tartar volatilized. 375
12. Repeated sublimations do not always increase the quantity of the sublimate. 376
13. The fourth way of introducing volatility into bodies. 377
14. A fifth way of rendering bodies volatile. 379

SECT. II.

15. Qualifications for fixedness in bodies. 380
16. The first way of producing fixedness, by means of fire, or the addition of other matter. ib.
17. A second way, by altering or expelling the volatile particles. 382
18. A third way, by securing rest. 383
19. A fourth way, by complicating the parts. ib.

Experiments relating to the superficial figures of fluids.

Various experiments to discover and illustrate the phenomena of contiguous fluids. 388

The atmospheres of consistent bodies.

1. **A**romatics and bodies of a loose texture, exhalable. 397
2. And those of a close and solid texture. ib.
3. As also cold bodies. 398
4. Various exhalations raised by means of fire from solid bodies. ib.

5. Very ponderous bodies yield effluvia. p. 398
6. Very solid, hard, and ponderous bodies yield them. 399
7. And even such as are fixed. ib.
8. The atmospheres of bodies excited by gentle heat. 400
9. Many more bodies may emit effluvia, and have their atmospheres, than men usually imagine. ib.
10. Bodies may exhale, without manifesting it by a loss of weight. ib.
11. Other ways, besides the statical, of discovering the effluvia of solid bodies. 401

The nature, properties and effects of effluvia.

SECT. I.

1. **T**HE strange subtilty of effluvia argued from the fineness of silver-wire. 404
2. Gilt wire. ib.
3. Silken threads. ib.
4. The small quantity of gold employ'd to gild silver-wire. 405
5. The rarification of water turn'd into vapour. 406
6. The rarification of fewel turn'd into flame. ib.
7. Gun-powder into smoke and flame. 407
8. The wonderful minuteness of parts in the first rudiments of a mite. 408
9. A subtile division of a grain of copper. ib.
10. Another of a grain of gold. 409
11. Animal effluvia affect the human body. 410
12. Even the effluvia of solids may penetrate solids. ib.
13. Large effluvia may but little alter the weight or bulk of bodies. 411

The Contents of the First Volume.

14. *A large quantity of space may be possessed by a very small one of rarified matter.* p. 413

15. *Contagious effluvia.* 415

SECT. II.

16. *The great efficacy of effluvia.* 416

17. *The several ways whereby the effluvia of one body may act upon another.* ib.

18. *The number of agents may supply the want of bulk.* 417

19. *Some effluvia very subtile and penetrating.* 418

20. *Especially when they act in swarms, and with great velocity.* 419

21. *Other modifications of motion may give vigour to effluvia.* 420

22. *Odd effects of lightning.* ib.

23. *And thunder.* 421

24. *Effluvia may produce great effects by exciting a communicative motion in bodies.* 422

25. *Particularly in those of men.* 423

SECT. III.

26. *The determinate nature of effluvia.* 425

27. *That effluvia may retain the nature of the substances which yield them.* ib.

28. *Illustrated.* ib.

29. *And proved by examples of their reunion.* 426

30. *By others observable in their sensible qualities.* 427

31. *Which would be more obvious if the human senses were more acute.* 428

32. *Some effluvia affect not men, but other creatures.* 429

33. *Examples of coalitions and resulting changes of steams.* 431

34. *Whence, probably, meteors, contagious diseases, and their removal.* 432

35. *The last way of determining the nature of effluvia, by their effects on bodies different from the organs of sense.* 435

The porosity of bodies consider'd.

SECT. I.

1. *THE porosity of animal bodies.* p. 439

2. *Shewn from the structure of their stable parts.* 440

3. *From the manner of their nutrition.* ib.

4. *From their sweat and perspiration.* ib.

5. *From the translation of morbid matter.* 444

6. *And from the ingress of effluvia.* ib.

7. *The harder parts of the body permeable.* 448

SECT. II.

8. *The porosity of solid bodies.* 450

9. *The porosity of wood.* 451

10. *Of earthen-vessels.* 452

11. *Of natural stones.* ib.

12. *Of metals.* 454

13. *Of glass.* 455

14. *The way of colouring glass.* 457

15. *Whether the art of staining glass be lost.* 458

The intestine motion of the parts of solids.

1. *REST what.* 460

2. *No bodies at absolute rest.* ib.

3. *An intestine motion in the parts of wood.* 461

4. *Stones.* ib.

5. *Diamonds.* 462

6. *And glass.* 463

Considerations upon the natural and preternatural states of bodies, especially the air.

1. *THE common notion of the natural and preternatural states of bodies, obscure, unjust, and liable to be misapplied.* 464

The Contents of the First Volume.

xli

2. *Whether water be not as properly thaw'd ice, as ice is frozen water.* 465
3. *Whether a liquid or a consistent form be the natural one of butter, &c.* 466
4. *Whether the atmosphere be in a natural or a violent state.* 467

Observations upon the effects of languid and unregarded motions.

1. **T**HE great efficacy of celerity. 472
2. *The force of fluids upon solids.* 473
3. *What is wanting in the bulk of some bodies made up by their number.* 476
4. *The propagable nature of motion.* 478
5. *The effects of the invisible motion of fluids upon animal bodies.* 483
6. *The efficacy of unregarded motions in fluids, upon inorganical bodies.* 485
7. *Various bodies not at rest, but in a state of tension, &c.* 487
8. *Many effects arise from intestine motion.* 491

The mechanical production of magnetism.

SECT. I.

1. **I**Ron may act as a load-stone. 496
2. *Magnetical qualities may be mechanically produced, destroy'd, or alter'd in the load-stone and in iron.* 497

SECT. II.

3. *Experiments and observations upon the load-stone itself.* 501

The mechanical production of electricity.

1. **T**HE hypotheses advanced to solve the phenomena of electricity. 506
- VOL. I.

2. *That electrical bodies act mechanically.* 507
3. *Electricity producible by mechanical changes.* 510

The mechanical causes of precipitation.

1. **P**recipitation what. 515
2. *Its causes inquired into.* ib.
3. *The mechanical ways of accounting for precipitation.* 516
4. *From the gravity and bulk of the dissolved body.* 517
5. *From weakening the solvent.* 520
6. *By presenting another body to be wrought on, &c.* 521

The mechanical origin of corrosiveness and corrosibility.

SECT. I.

1. **T**HE theory of corrosiveness. 526
2. *Confirm'd by experiments.* 527

SECT. II.

3. *The theory of corrosibility.* 534
4. *Confirm'd by experiments.* 535

The mechanical production of tastes and odours.

SECT. I.

1. **T**HE mechanical cause of tastes. 537
2. *A body, almost insipid, divided into two bodies, of very strong and very different tastes.* 538
3. *Two bodies, the one highly acid, and the other alkalizate, produce a third almost insipid.* 539
4. *An insipid mixture of bitter and salt bodies.* ib.
5. *An insipid mixture of sweet and salt bodies.* 540
6. *An*

The Contents of the First Volume.

6. An insipid body and a sour one make another more bitter than gall or aloes. 540
 7. An insipid body and a corrosive one made into a sweet substance. ib.
 8. Liquors corrosive enough to dissolve metals, obtain'd from the sweetest bodies. ib.
 9. A body bitter in the highest degree, divided into two substances, the one extremely sour, and the other perfectly insipid. 541
 10. Variety of tastes produced in one insipid body, by associating it with different menstruums. ib.
 11. Variety of tastes produced with one menstruum, by associating it with insipid bodies. ib.
 12. Two liquors, the one highly corrosive, and the other very pungent, compose a body of a pleasant aromatic taste. ib.
 13. The peculiar tastes of natural bodies imitated by art. 542
 14. Some changes made of tastes by maturation. 543
- SECT. II.
15. The mechanical production of odours. 544
 16. A strong smell produced by two scentless bodies. ib.
 17. A strong scent produced by water, in a body which had none before. ib.
 18. Produced odours differing from that of any of the ingredients. ib.
 19. The production of odours by local motion. 545
 20. A scented body deprived of all its smell by mixing with an inodorous one. ib.
 21. A pleasant aromatic odour produced by putting a fetid body to another not sweet. ib.
 22. A fragrant odour produced by two bodies not well scented. ib.
 23. A pleasant and aromatic smell given to spirit of wine, by the addition of an inodorous body. ib.
 24. The foremention'd fragrant body brought to smell like garlic. 546
 25. The smell of musk produced with an inodorous body and another not well scented. 546
 26. Pleasant smells produced with fixed metals, and fetid or scentless bodies. ib.
 27. Good smells heighten'd by composition. 548
- The mechanical origin of heat and cold.
- SECT. I.
1. THE origin of cold mechanical. 550
 2. To produce a great degree of coldness at any time of the Year. ib.
 3. A coldness produced by the mixture of warm bodies. 553
 4. Heat produced by the mixture of cold bodies. 554
 5. Ebullition no argument of heat. ib.
 6. The same body that cools some liquors, may heat others. 555
 7. Potential coldness. ib.
 8. Heat produced by the joint action of two bodies upon a third; with which separately they produce cold. 557
 9. Heat and cold accidentally varied in their production. 558
- SECT. II.
10. Heat mechanically producible. 560
 11. Agitation requisite to Heat. ib.
 12. And various Determinations. ib.
 13. That the moving particles should be small. 561
 14. Various mechanical ways of producing heat. ib.
 15. Heat produced by mixing the same body with others of several kinds. 567
 16. Other

The Contents of the First Volume.

xliii

16. Other ways of producing heat in solids, powders, metals, &c. 570

Memoirs for an experimental history of cold.

1. **H**Eads for the natural history of cold. 573
2. Our senses and the common thermometers may misinform us of cold. 574
3. Observations upon the defects of thermometers; and the sealed kind of that instrument consider'd. 579
4. The cause of the air's condensation consider'd, with the ascent of water, by cold, in the common thermometers. 584
5. Experiments with bodies capable of freezing others. 588
6. Experiments and observations upon bodies disposed to be froze. 592
7. Solid bodies frozen. 594
8. Experiments upon bodies indisposed to be froze. 596
9. Experiments and observations of the degrees of cold in several bodies. 598
10. Experiments relating to the tendency or direction of cold. 601
11. Experiments and observations with regard to the preservation and destruction of bodies by cold. 603
12. Experiments relating to the expansion of water, and aqueous fluids in freezing. 610
13. Experiments relating to the contraction of liquors by cold. 613
14. Experiments in consort, relating to bubbles, the supposed cause of levity in ice. 615
15. Experiments to measure the expansion of liquors by cold. 620
16. Experiments to discover the expansive force of freezing water. 623
17. Experiments relating to a new method of estimating the expansive force of congelation, and of highly compressing air without engines. 626
18. Experiments and observations upon the sphere of activity of cold. 629
19. Experiments upon the different mediums thro' which cold may be diffused. 631
20. Experiments and observations upon ice. 633
21. Experiments and observations upon the duration of ice and snow, and the destruction thereof by air and several liquors. 638
22. Considerations and experiments upon the Primum Frigidum. 640
23. Experiments and observations upon the coldness and temperature of the air. 650
24. Strange effects of cold. 665
25. Experiments upon the weight of bodies frozen and unfrozen. 673
26. Promiscuous experiments and observations upon cold. 677
27. The vulgar notion of an antiperistasis examin'd. 689
28. Mr. Hobbs's doctrine of cold examin'd. 711
29. Whether cold be a positive or privative thing. 719



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THE
P R E F A C E.

TO shew the usefulness of a philosophy is to shew its excellence. That the experimental kind is most highly useful, the following pages, by a vast variety of particulars, abundantly manifest. Indeed, the modern philosophy, which builds upon experiments, is wholly applicable to the purposes of life and the phenomena of nature; and seems now to be entirely prosecuted in that view; whereby it is advanced far above all the systems that went before it.

Since the late happy conjunction of mathematics and philosophy, and the application of them both to matter and the bodies about us, many noble discoveries have been made, all tending to enlarge the understanding and to give us a command over nature. To this end, the industry of the moderns has made use not only of later inventions, but also of those of the ancients. Thus, for example, the old geometricians demonstrated abundance of fine properties in the ellipsis and the parabola; and of late the motions of the planets, comets and projectils are demonstrated to be performed in these lines: an use the ancients never dream'd of! By this means, at length, a just theory of the celestial bodies is establish'd, and the whole astronomical world levell'd to our capacities. Hence another new scene is also open'd; for mathematicians thus becoming mechanics have furnish'd us with numberless new instruments and engines for various uses. Microscopes and telescopes, unknown to the ancients, are now commonly applied to discover the wonders of nature both in her smallest and largest productions; and serviceable machines are every where employ'd to save the expense of animal strength; models and imitations are made of nature's works, and the world with its various phenomena clearly represented in miniature. In short, philosophy is brought down and confin'd to material objects, and such things as we know

P R E F A C E.

to have a real existence; which is now allow'd to be the proper and only way of applying and improving it. And in this sense Mr. Boyle understands experimental philosophy, and treats it accordingly.

If any thing shall seem liable to exception in the following piece, either as to the matter or the style, the reader is desir'd to take notice, that Mr. Boyle wrote a great part of it whilst he was very young, and the whole in a familiar epistolary way.



THE USEFULNESS

OF

Experimental Philosophy;

By WAY of

EXHORTATION

TO

The STUDY of it.

In THREE Parts.

PART I.

Shewing the advantages that accrue from natural philosophy to the mind of man.

SECT. I.

AS the natural philosophy I wou'd recommend is much more difficult, laborious and expensive than that of *Aristotle* or the schools, 'tis necessary, before we descend to particulars, to apprize the reader of its ability to recompence whatever time and pains can be thereon bestow'd.

And, methinks, a due reflection upon that saying of *Pythagoras*, the author of the modest title philosopher, "to know the truth and to do good are

B 2

*Our inquiries in-
timate rewarded
by an increase of
understanding and
a power to do good.*

The Usefulness of Philosophy.

“the things that chiefly enoble man, and make him resemble the Gods” might endear the study of philosophy to us. For, as the soul is endow’d with two principal faculties, the understanding and the will, the former whereof is adorn’d and perfected by knowledge, and the latter improv’d and render’d amiable by goodness; so nothing more gratifies and enriches the one, or more enables the other to do good than natural philosophy.

But to shew this more distinctly, I shall here consider a few of those numerous advantages which accrue to mankind from the study of nature: the chief whereof tend to instruct the understanding, to gratify our curiosity, and to raise and cherish our devotion.

And as not only *Aristotle* but common experience shews, that all men are naturally desirous of knowledge; this propensity must strongly attach us to those works of nature which are ever present to our senses, and continually solicit our inquiries. Even the school philosophy, though so litigious in its theory and barren of fruit, has had its zealous admirers; who cou’d surely be render’d such by nothing but this in-bred fondness for its pretended end and object.

Again, the same author, taught by *Plato*, observes that admiration by raising our curiosity is the parent of philosophy; as we live, therefore, among wonders, they must of necessity strongly invite us to a contemplation of nature’s works; some whereof, being obvious and legible, amaze an ordinary spectator; whilst others are admirable and abstruse enough to astonish the most curious and inquisitive.

The bare prospect of this magnificent fabric, the universe, furnish’d and adorn’d with such a strange variety of curious and useful objects, might transport us with joy and wonder, did not their commonness prevent such an effect. That this wou’d otherwise happen appears probable from what *Mr. Stephens* the oculist, and another illustrious eye-witness, lately told me of a maid, who, being born with cataracts, continued absolutely blind till about the age of eighteen; but being then brought to the free enjoyment of sight, she was so ravish’d upon beholding the many new presented objects, so transported at most of them, and, in a word so far distracted as to explain that mystical *Arabian* proverb “Shut the windows that the house may be light.”

But if a slight view of this admirable structure be capable of pleasing so highly, what satisfaction must it afford a spectator able to comprehend and relish the curious workmanship and contrivance of it? For, the book of nature, I conceive, appears as differently to an ordinary gazer, and to a naturalist, as an excellent book of hieroglyphics wou’d to a child and to a philosopher; the child wou’d be pleased with the oddness and variety of the pictures alone; whilst the philosopher wou’d not only be delighted with the same, but receive a much higher satisfaction in contemplating and acquiring the veiled and abstruse truths that were dexterously couched therein.

For as the understanding is the highest faculty in man, so are it’s pleasures the highest he can naturally receive. I am not, therefore, surpriz’d that *Archimedes*, when happening, in a bath, upon a way to solve a perplexing difficulty, shou’d instantly leap out, and run naked about the streets, crying aloud “I have found it, I have found it;” nor that the elder *Pliny* cou’d not be deterr’d by the

dissuasion

The Usefulness of Philosophy.

5

diffusion of friends, the flames and hideous eruptions of *Vesuvius* from searching into the nature of such *Vulcanos*, and, as it happen'd from losing his life by too near an approach. For, in like manner, we daily see chymists hazard their lives among their furnaces, whence the fumes that issue prove sometimes fatal.

To converse with dead and putrid carcases were, one wou'd think, a shocking and odious employment, yet some anatomists dote upon it: and, I must own, it's usefulness has greatly enamour'd me with dissection. For although the fine works of artificers seldom fail to draw the curious and raise their wonder; and though, in my travels, I have often, with difficulty, purchased the sight of a master-piece of art, yet, at present, a skilful dissection wou'd please me better than the famous clock at *Strasburgh*. So that *Aristotle*, in my opinion, acts like a true philosopher, when dropping the consideration of the sublimest natural productions, he descends to record the homely history of animals, "We come now," says he, to the nature of animals, with a resolution to comprize all we can, be it base or noble."

'Tis a farther recommendation of natural philosophy that the truths it teaches highly gratify without the least disgusting the mind; being such as conscience never upbraids us with in the enjoyment, nor turns to torments afterwards. Neither are these truths obtain'd by that low kind of employment which, tho' not condemn'd by religion, cannot stand the test of reason; for even the most rational and strictly virtuous men have employ'd themselves herein. *Pythagoras*, *Democritus*, *Plato*, with numberless others, fam'd for wisdom, thought philosophy demanded not only their studies at home, but travelling to the eastern countries, where it was best taught, in order to obtain. And that rigid teacher *Seneca*, not content through his other writings frequently to extol the contemplation of nature, left us seven books upon the subject.

Philosophy whilst it gratifies does not disgust the mind; but is an employment worthy of it.

How far religion countenances this pursuit we shall see hereafter; but reason tells us 'tis worthy of a rational creature: since those who have advanced reason to the greatest height have been herein most studiously engaged. Nay, this noble faculty, conscious of its own abilities, upon due application, is affronted when not thus considerably employ'd; whilst we become guilty of our own degradation, who being furnished and placed, as we find our selves, regard this vast and instructive universe, the noblest part whereof we are design'd to make, as slightly as such animals to whom lower faculties and prerogatives are assign'd. *Aristotle* well observes that "Man is the only animal of an erect stature, and "that because his nature participates of something divine; the properties whereof "are understanding and wisdom." And certainly, it ill suits the dignity of such a creature to live in ignorance of the laws of that great common-wealth, the world, whereof he is the most eminent member. Nay, as it is injurious, so, did not custom or sensuality stupify us, it must also be afflicting to a rational mind, not to understand the structure and contrivance of the body wherein it resides, and by means whereof it acquires all the knowledge it has.

Indeed, the generality of men, how indolent soever, come by the superiority of their faculties, which enables them to reflect, in some degree, to know more than brutes; but, if contented with the first appearances of things, we rely upon our nature, without the help of industry, we wilfully lose the noblest

use

The Usefulness of Philosophy.

use and highest satisfaction of our reason; and whoever is thus wanting to himself, may be said to lead the life of a spider in a palace, who takes notice of nothing there but what passes in her own web.

To give the greater sanction to philosophy, it may be observ'd, that according to *Josephus*, *Seth* and his posterity, stiled the sons of God, first cultivated astronomy. It was a general tradition, that *Abraham* first instructed the *Egyptians* both in astronomy and philosophy; and *Berosus*, as cited by *Josephus*, records him to have been skill'd in the science of the stars. And speaking soon after of *Abraham* and the *Egyptians*, 'tis said expressly, "that he ingenuously communicated to them the sciences of arithmetic and astronomy; for the *Egyptians* knew nothing of either, before he came among them".

But to put it beyond question, that the greatest genius need not blush at the study of natural philosophy, *Solomon* himself not only cultivated, but taught it; and left behind him writings on that head, from whence if some Rabbi's say true, *Aristotle* borrowed most of his choice pieces; tho' the originals descended no lower, left, say the Rabbi's, they should have been idoliz'd, or all kind of debauchery committed, in hopes that the diseases consequent thereon, might thence have been easily remedied.

The variety of
nature excites our
inquiry.

From the entertaining variety of nature's works, we are again instigated to their contemplation; for whilst most other sciences are so limited, that one of the best systems thereof will usually contain all that is known upon each head; the objects of natural philosophy, being as numerous as the laws and works of nature, are so various, that the age of *Methuselah* wou'd fail before the subject. Nay, so fertile is each particular object of a naturalist's contemplation, that several might be named, to discover all the useful properties but of any one in the number whereof, a single life wou'd be insufficient. 'Tis almost incredible what variety of vegetables the earth produces: botanists have, long ago, enumerated six thousand; and many more have been since discover'd. I lately had a peculiar and excellent kind of pepper sent me from *Jamaica*, the shell whereof tastes like cinnamon, but smells like cloves; a vegetable unknown to the botanists of our country. Whole treatises however, have appear'd upon single plants. *Themison*, according to *Pliny*, publish'd a volume upon plantain; *Amphilochus* one upon trefoil and hadder; and king *Juba* another about a species of water-lilly. To come to later times, *Carolus Rosenbergius* wrote a book upon roses, and *Martinus Blochwitzius* one about elder. Among the chymists *Angelus Sala* publish'd separate treatises of vitriol, tartar, and sugar. *Unzerus* too, wrote particular tracts upon mercury, sulphur, and salt; as did also *Paracelsus* upon St. John's wort, arsmart, hellebore, and some other plants. *Basil Valentine*, a candid chymist, publish'd an excellent treatise of antimony, which was afterwards improved upon by *Angelus Sala*; nor were there wanting many other useful treatises of the same subject, to confirm *Basil Valentine's* sayings, "'Tis impossible for one man to discover all that is discoverable in antimony". As a farther confirmation whereof, I, my self, lately directed the drawing of an actual quicksilver of antimony, very different from any I had before met with. I have, likewise, a peculiar way of separating from this drug a combustible body that is scarce distinguishable from common brimstone; and gain a menstruum by distilling French verdi-

verdigrease in a strong, naked fire, which makes a blood-red tincture of the glats of antimony much more expeditiously than that used by *Valentine* and his followers. This menstrum also being drawn off, leaves a calx that will yield a red tincture with spirit of wine.

When chymists expose several consistent, but not fix'd bodies, to the action of the fire, they usually do it in vessels, either open, as when they make calx, or glass of antimony, or, at least, in such as are not so close, but that air is included with the matter; and tho' they regard not this included air, because usually there is not much of it in the vessel, yet it may have a considerable influence on the effects of the fire; not only as it contributes to the ascent and sustentation of the dissipated parts of the mineral, but as it affords these corpuscles opportunity to fly about in it, and thereby to make associations or coalitions and concretion that otherwise would not be produc'd. Upon this account, it may often be of use to employ a method, to secure the body expos'd to the action of the fire, from the contact of the air; whereby the parts of the body, and perhaps the igneous corpuscles, will be reduced to act reciprocally upon one another, without causing any considerable dissipation, or avolation of parts.

To apply this to antimony, we take of that mineral well powder'd, and of white chalk well dry'd, reduc'd likewise to powder; with these in a large earthen pot or crucible, we make several layers, leaving the lower and uppermost bed of chalk, and the last thicker than any of the rest; and taking care that none of the layers of antimony are too thick, that the heat may penetrate them the better; we cover the vessel, put it among the kindled coals of a digestive furnace, and there keep it for a competent time; which, according, to the bigness of the pot and the strength of the fire, may be a day and a half, and sometimes above two days.

But to proceed, the learned *Kircher* has given us a *folio* volume of light and shadows, and a *quarto* upon the load-stone; yet our *Gilbert*, and since him *Cabeus* wrote on the same subject; which tho' *Kircher* has more lately prosecuted in a voluminous work, I am of opinion there's room enough left for farther improvement; having my self very lately made a remarkable experiment with that wonderful stone.

Even the smallest productions of nature may solicit and reward our inquiries. *Pliny*, treating of insects, is transported with admiration at the workmanship shewn in them "The contrivance of nature, says he, is no where more conspicuous or more visibly collected than in these minute creatures" And after this he handsomely admonishes his reader that no subject of natural knowledge is contemptible or superfluous. From considering the skin on the sole of the foot *Galen* admired the wisdom of God; and he excellently said "tho' some creatures seem made of coarser materials than others, yet the maker's art shines through the despicableness of the vilest matter: the ignorant indeed, admire the beauty of the materials, but artists are struck with the workmanship of things." And *Aristotle* coming to treat of the parts of animals prevents his reader from thinking the meanness of the subject should render it despicable. Nay, the haughty *Paracelsus* condescended to write a book about the mysteries of worms, wherein he justly reprehends the laziness and pride of those physicians "who neglect and contemn all

The Usefulness of Philosophy.

"all inquiries into nature, and receive the fruits thereof from others with scorn and derision" he adds, "God has created nothing so vile or despicable that may not turn to the use of man." And certainly whatever God has thought fit to make we should not think unworthy to know; for a human mind cannot be debased by a notion of what was form'd according to a divine idea: and therefore, *Solomon* treated as well of reptils as of nobler animals, as well of the ezob on the wall as the cedars of *Lebanon*. And durst I propose my own actions for examples, I shou'd say, tho' my condition, God be prais'd, enables me to make experiments by other hands, yet have I never refused to dissect any kind of animals, nor in my laboratory, to handle lute and charcoal.

*Philosophy gives
us the command of
nature.*

But farther, philosophy is not only delightful as it brings us acquainted with nature, but also as it often instructs us to command her; for the naturalist knows many things of which others are ignorant, and performs what they cannot; because he not only understands, but in some measure, imitates, multiplies and improves several of her extraordinary works. And how naturally we affect the use of this power may be seen in children, who, from a seeming innate propensity, delight in endeavouring to change the productions of nature. And so extensive is the naturalist's power, tho' he cannot produce one atom of matter, that he can introduce numberless forms and work surprizing changes among bodies: so that were *Adam* to revive and survey that vast variety of man's productions to be found in our shops and magazines, he would admire to see what a new world had, by the industry of his posterity, been added to the old one.

'Tis true, indeed, man is but the minister of nature, and does no more than apply agents to patients, yet by his skill in such application he gains dominion over creatures otherwise much stronger than himself; and can even perform such things as to another man shall appear astonishing. Thus the poor *Indians* thought the *Spaniards* more than men because their knowledge of gun-powder enabled them to thunder and lighten destructively. And this empire of man over the creatures may to a sound, philosophical mind prove more satisfactory than that for which bloody contests frequently arise; for the latter being only a gift of nature, or a present of fortune, and often the purchase of crimes, argues no real superiority in the possessor; but the latter is a power becoming man as man. Perhaps also, the surprizing things perform'd by an ingenious man give him a higher satisfaction as being proofs of his knowledge than as they are instances of his power or means of increasing his wealth.

SECT. II.

*Whether philosophy
leads to athe-
ism.*

Another advantage of philosophy, we said, was the raising and cherishing our devotion. But many eminent divines, it seems, out of an holy jealousy for religion, represent this study as unbecoming a christian, and leading to

The Usefulness of Philosophy.

9

to atheism; "because, say they, by enabling men to account for all surprizing appearances from second causes, it brings them to disbelieve a first"; which objection, were it well grounded, wou'd cause me to condemn what I am now recommending: for I had much rather have men christians, and ignorant of nature's mysteries, than philosophers, and deny the author of nature. Now, tho a well-meant zeal may defend the persons of these gentlemen; yet their doctrine has too bad a tendency to be left unanswer'd. But not to mix too much divinity with a philosophical discourse, I shall here only give the heads of a reply.

And first, tho' it were presumption in man, "who is but of yesterday", to pretend to assign all the ends of God in the work of creation; yet surely it may humbly be supposed, that two principal designs of his creating this system, were the manifestation of his own glory and the good of mankind; because sacred writ, in abundance of passages, assures us of the former; not to mention heathen authorities. And that none of God's works might want intelligent spectators, tho' man was not formed till the sixth day, the angels, as 'tis generally supposed, were created on the first. The other design appears from the time of man's creation, which was kindly deferr'd till all things were prepared for his reception; from the commission given him "to replenish the earth and subdue it"; by the placing of noble luminaries "to give light upon the earth, and divide between the day and the night"; the same is also farther confirmed by other texts of Scripture. And accordingly, God caused the sun to stand still at one time, to go back at another, and has frequently either suspended or alter'd the laws of other parts of the universe, for the instruction or benefit of man. On the other hand, upon Adam's transgression the ground was immediately "cursed for his sake"; even the face of the earth was destroy'd for the sins of *Sodom*; and the other animals as well as men perish'd, in the deluge. So also "in the last days, when the earth shall be replenish'd with scoffers", unexpected flames will either destroy or transform the world.

Two principal designs of God in creating the world.

The same is evident also from reason; for as in this visible world, man alone is capable of enjoying many of the other creatures; and of discerning the excellence of the creator in them; 'tis plain they were made for man. 'Tis not for themselves, that rubies flame or diamonds sparkle; that bezoar is antidotal, or that trees are yearly exhausted in profusion. That light the sun around diffuses, is useless to himself, an inanimate Being; but entitles him minister to the system. Animals alone, among the creatures, have a sense of their own existence, and of these, only man acknowledges all the rest to be the gift of God, and glorifies him for them; a truth acknowledg'd by *Christians, Jews, and Heathens*. The inference I wou'd make from all which is, that, whoever deters men from studying nature, would frustrate God of the above-mention'd ends of creation. For besides that the corporeal delight and advantage we are capable of receiving, must be greatly obstructed through ignorance of natural philosophy, as will hereafter be made evident; our spiritual happiness depending upon religion, the greatest benefit we can receive from the things of this world, is their increasing and cherishing this grand principle, and thereby rendering us acceptable to God; and both these effects they were, doubtless, design'd to have on us.

The Usefulness of Philosophy.

For, to suppose innumerable creatures sent into the world only to feed and please mankind, but not to afford them any instruction, is like imagining a prudent merchant wou'd furnish his friends with numberless curiosities and necessaries for a voyage, without allowing them the use of a sea-chart or compass.

Moreover, God himself lays us almost under a necessity of inquiring into his works. The book of *Genesis* begins with a description thereof, and descends to a detail of each day's proceedings in the creation and tho' the scripture usually condescends to the conceptions of the vulgar, yet the two first chapters of *Genesis* perhaps afford finer hints of natural philosophy than men are hitherto apprized of*. Beside, there are many texts in sacred writ unintelligible without a previous knowledge in natural philosophy. Many passages therein allude to the properties of animals, as that precept of our Saviour, "be ye wise as serpents, and harmless as doves". And so necessary has natural knowledge been thought to illustrate texts in scripture, that abundance of learned men have publish'd whole treatises of the animals, stones, and other works of nature mention'd in that book. Nor shou'd the theme be discontinued, for there remain many passages of it not to be understood without penetrating deep into nature's mysteries.

The attributes of
God manifest in
his creatures.

But to come to the attributes of God, manifested in his creatures; the most conspicuous are his power, his wisdom and his goodness; and the same may also, tho' differently and more obscurely, be found in the bible. How eminently is the first of these display'd in making all things out of nothing; and, without materials, raising this immense fabric, whose dimensions are so prodigious, that even a mathematical demonstration can hardly render them credible? To pass by elephants and whales, mountains and seas, as inconsiderable objects, the globe we inhabit, tho' by the common computation, no less than 22,600 *Italian* miles

* These hints seem to have been well consider'd and employ'd by the Rev^d. Mr. *Whiston*, who, from them and the *Newtonian* system of philosophy, has nobly attempted to give a rational and philosophical account of the creation, in agreement with the *Mosaic* history of it. This author first supposes that the *Mosaic* creation is a bare historical narrative of nothing but the formation of the earth out of a chaos, and of the successive visible changes, each day made therein, till it became a fit habitation for mankind; and that this history is to be understood in the obvious literal sense, unless where an evident reason can be given for the contrary. He then proceeds to shew, that the rudiments of the earth were the atmosphere of a comet; that the annual motion of the earth commenced at the beginning of the *Mosaic* creation, but its diurnal rotation not till after the fall of man; that the orbit of the earth was a perfect circle before the deluge; that all the small bodies which compose the earth, being originally in a mix'd confused fluid state, were the chaos; that the upper regions thereof, before the beginning of

the *Mosaic* creation, were involved in a thick darkness, which dissipated, by degrees, as the parts of the chaos subsided, according to their specific gravity. The first day's work was according to our author, the production of light, or the successive arrival of some of the sun's rays to all the parts of the earth; on the second day the air with its vapour was elevated and spread out above the earth; on the third the inferior waters were collected into seas, whence the dry land appear'd with its vegetable productions, the vapour in the air being sufficiently rarified: on the fourth the celestial bodies became visible. And now the terraqueous globe being habitable, fish and fowl were produced on the fifth day, land animals on the sixth; and lastly man. But Mr. *Whiston* will not allow the earth to be so hasty a production as is usually supposed; for he endeavours to shew, that, as at first, it had no diurnal rotation; so what *Moses* calls days were in reality years. The reader, who desires farther satisfaction, may consult the second edition of Mr. *Whiston's New Theory of the Earth*.

The Usefulness of Philosophy.

II

in circumference, is but a point compared to the firmament; as we learn from the parallax of the fix'd stars. And according to *Ptolemy*, the sun is not only 166 times bigger than the earth, tho the distance between them be 1165 of the earths semidiameters; that is by *Gassendus's* computation, so many times 4177 miles; but also that the smallest fix'd stars are conjectured to be 18, and the largest 108 times bigger than the earth. The *Copernicans* carry their computations higher, for *Philippus Lansbergius* supposes the earth's orbit, the semidiameter whereof is computed 1500 times bigger than the earth's, to be but a point in regard of the fix'd stars, which he takes to be removed from the earth 42,000,000 of its semidiameters, or 175,434,000,000 miles; a surprizing distance *! And tho' we allow for inaccuracies, and the differencies of observations, whence such computations are made; yet as the fix'd stars are perhaps placed such different distances from the earth, that tho' they appear different, yet they may all be equal in magnitude, the earth can be but a point in respect to the heavens.

The next attribute of God, his wisdom shines so strongly in his creatures, that an intelligent spectator, considering them in any determin'd view, cannot fail to discover it. So endless a multitude and variety of birds, beasts, fishes, reptils, herbs, shrubs, trees, stones, metals, minerals, stars, &c. each whereof is perfectly enabled to answer the ends of its creation, bespeak a wisdom infinite, and extort the exclamation of the *Psalmist*, "How manifold are thy works, O Lord; in wisdom has thou made them all". And how highly soever some naturalists may value themselves, yet the utmost they can do, is to understand and applaud, without rivalling, the works of the Almighty. For as a novice, when a curious watch is taken to pieces before him, may discern the excellence of the contrivance, without being able to make so artificial a machine; so the anatomist, by frequent dissections, learns the admirable structure and use of the parts of a human body, tho' he cou'd not before devise how all the animal functions might so well be perform'd.

Thus, late experiments having shewn the use of the blood's circulation, and of the valves in the heart and veins, (which, the famous *Dr. Harvey* told me, gave him the first hint of his grand discovery) we at length acknowledge the

His wisdom.

* In the year 1720. *M. Cassini*, by the command of the King of France, exactly measured seven degrees and a half on the earth's surface, where by he found, supposing the earth to be a sphere. one degree to contain 343,752 French feet, which agrees as exactly as cou'd well be expected with the former mensuration made by *M. Picart*, where by there are allow'd 342,360 feet to a degree; and with that of *Mr. Norwood*, which assigns 367,196 English feet to the same. Hence the circumference is 123,750,720 French feet; and supposing the earth a sphere, its diameter 39,391,077 feet. But the earth being higher at the equator than at the poles, *Sir Isaac Newton* makes its greatest semidiameter 19,767,630.

and its least 19,609,820 French feet. The proportion of the English foot to the French, is nearly as fifteen to sixteen. See *Newton. Princip. Edit. 2. p. 378, 387. Memoir. de l' Acad. Roy. Ed. Amst. A. 1701.* The distance of the earth from the sun is now computed at 81,000,000. miles; and the modern astronomers allow the sun to be in magnitude 900,000, and in quantity of matter 230,000 times bigger than the earth. The fixed stars are each supposed the sun of a system like this of ours; and supposing their parallax 45'', to be distant from the sun, about 700,000,000 miles. See *Huygen. Cosmoch. p. 14. 135. Newton. Princip. p. 482. and Philosoph. Transact. N° 209. p. 101.*

The Usefulness of Philosophy.

wisdom of the contrivance, after it had escaped the search of many preceding ages.

And tho' God's greater works declare his great power and wisdom, yet the latter is no less manifest even in the smallest creatures. For, as the skilful *Protagoras*, by the extreme neatness and almost undiscernible fineness of a stroke, discover'd it to come from the hand of *Apelles*; so God in these minute creatures often draws traces of omniscience too delicate to be ascribed to any other cause. Elephants to me appear less admirable than moles, whose eyes are manifestly design'd to see only the light, not other objects, by its means; and whose feet are adapted to dig themselves a way under ground. And however meanly the vulgar may think of some minute creatures, my curiosity, I own, determines me to the smaller kind. A gentleman, return'd from *Jamaica*, told me he had seen in that island a great number of trees, which bear the silk-cotton, and found many of them to surpass, in bulk and height, the larger sort of our *English* oaks; and that on a mountain, which many, out of curiosity, went to visit, he saw a stupendous silk-cotton tree, that was twenty one yards circumference in the body. The same person assured me he saw a cannow made of the hollow trunk of one of these trees, which, after all that had been taken off to give it the shape of a vessel fit for service; was thirty feet about, and of a proportionable length. But the humble sensitive plant and abject load-stone, delight me more than lofty oaks or monstrous rocks. An ant-hill has given me more pleasure than the *Alps*; which lessens my admiration, that the ant was an object of *Solomon's* contemplation. The silk-worm raises my wonder more than those outlandish monsters, which multitudes flock and pay to see. 'Tis true, seas and mountains, with other immense productions of nature, proclaim God's power; but the curious contrivance of some animals, so small, that they seem all workmanship, demonstrates his wisdom no less than those; so that not only "his greatness, but also his understanding is unsearchable". Add to this, the inconceivable variety there is of animals, in whose contrivance the great former of all things has display'd an almost equal skill. Such reports are given us of the immense bulk of elephants, that they seem incredible. *Gassendus* tells us of one in the year 1631 that weigh'd near 5000 *Roman* pounds, of twelve ounces each; which appears probable from the bigness of some elephants teeth; one of which, according to *Linſchoten*, will weigh 200 pounds, tho' each pound consist of twenty four ounces. On the other hand, not to mention that animal, bred in wax, suppos'd by *Aristotle* the least in nature; compare a cheefe-mite of near a grain in weight, tho' several together will scarce equal that, to the small elephant abovemention'd, and you'll find him exceed the mite near 28,800,000 times. Notwithstanding this, the limbs, and even the hairs growing on the legs of this minute creature, have thro' a microscope appear'd distinctly to my self and others. Consider now, what delicate skill it requires to contract into so small a compass the numerous parts of this little creature; to assign the proper number of them to its eyes and other organs of sense; to its head, stomach, and intestines, &c. and how exceeding subtile that nervous fluid must be which moves such little limbs. But farther still; as we have found these small creatures to be hatch'd from eggs, if the process imitates that of chickens, how very minute must be their recently animated parts; for in the eggs of
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hens, I have seen the limbs of the live chick clearly delineated, whilst it kept so close between the white and the yolk, where 'tis generated, that they both appear'd entire, and included in their respective membranes. 'Tis surprizing what vastly disproportionate masses of matter God has form'd into living creatures. To pass by other accounts of whales, *Jo. Faber Lynceus* saw, in the year 1624, a dead one, thrown up near *Santa Severa*, about thirty miles from *Rome*, that measured ninety one palms in length, and fifty in thickness; with a mouth capable of admitting a man on horseback, and a tongue the length of twenty palms. He adds, that four years before this, there was another thrown on the island *Corfica*, near the coast of *Italy*, an hundred feet long, big with a cub of thirty feet, that weigh'd 1500 pounds. But to shew the disproportion between this kind of fish and common elephants, "the solid fat, alone, of the whale weigh'd, says our author, 135,000 pounds", that is twenty seven times more than the whole elephant mention'd by *Gassendus*. And as the creator has made fish of such an enormous size, that the ocean seems only a suitable pond for them; he has also framed others that live in fluids, so inconceivably small, that many thousands of 'em will not amount to a grain in weight. For by the help of a good microscope, comparing one of those creatures found in vinegar, with a cheese-mite, we thought the fish almost as slender as one of the legs of the mite. Considering, therefore, what a vast quantity of matter the creator can fashion into a whale, and in how little compass he can contrive all the parts that constitute a fish, we must say with the *Psalmist*, "there is none like unto thee, O Lord, neither are there any works like unto thy works".

The third attribute of God manifested in the creation, is his goodness; where-^{H's goodness.} of every creature partakes, both in its first existence, and preservation of its state, till some higer end calls for its dissolution. But this goodness is chiefly conspicuous in animals, who, tho' some of 'em don't more acknowledge, are yet more capable of enjoying his bounty, than inanimate Beings. For, omitting that God, in scripture, is stiled, "the preserver both of man and beast"; and that he is said "to give food to the young ravens", what excellent provisions are made to continue the various and numberless species of living creatures? In a more particular manner does the goodness of God appear towards man, whom he has honoured with his image, and placed over most other visible creatures, which, either by his superior power or knowledge, are render'd serviceable to him; even the vast celestial bodies, tho' immensely distant from us, are, by mathematical skill, brought to serve our purposes; as to measure time, and shew the longitudes of places. The stars afford us light; we breathe the air, and receive the benefits of fire both in the kitchen and the laboratory: the earth supports our buildings, the clouds water our land, the sea and winds convey our ships to remotest regions, and return them fraught with all the choicest productions of art and nature; beasts innumerable are destin'd to feed, to cloath and carry us; flowers and jewels to delight and adorn us; fruits to sustain and refresh us; stones and timber to lodge us, and simples to cure our diseases; in a word, the whole world is only our magazine; and nature seems wholly employ'd to accommodate and delight us. For, perhaps, there's not a plant or animal, a metal or a mineral, of all that infinite number we possess, how despicable soever it may seem, which might not,
by

The Usefulness of Philosophy.

by a knowledge of its nature, become serviceable to man. The sparkling diamond yields in virtue to the dull load-stone, that author of commerce to many regions of the world; the lion, the eagle, and the whale are, together, less useful than that mean insect the silk-worm. And to regard the intrinsic value of things, and their medicinal virtues, doubtless, we trample upon many, that, did we know their uses, might serve the noblest ends. For certainly, all the properties of concretes, and virtues of common simples are not hitherto known; since new discoveries are daily made herein. What a large collection of this kind does *America* afford us? "Many excellent trees and shrubs, says *Piso*, besides "plants without number, are here usually very different in their form, leaves "and fruits from those of the old world: and the same holds good of birds, "beasts, fish and insects". And to give a signal instance of the latent powers in *American* simples; how very effectual has the *Peruvian* bark been lately found both at *Rome* and *London* against quartan agues? For tho' this medicine be depreciated by some, as being rather palliative than curative; yet according to Sir *Kenelm Digby*, 'tis so thro' the patient's rather than the physician's fault; for he solemnly assured me, that of between twenty and thirty persons, whom he cured of quartans by this remedy, not two relapsed. Nor can it be question'd that we have unknown plants of extraordinary efficacy at home. I my self have often gather'd an unpromising plant, called rue-leaved whitlow-grass, which slightly infused in beer, to my knowledge, lately, without pain, and in few days, cured a kinsman of Sir *Kenelm Digby*'s of the king's-evil; yet I don't find any botanist recommend it for that distemper. But this bounty of God to man seems abated, 'tis said, by permitting some poisons. To this it may be replied, that many poisonous bodies contain their own antidotes; and according to *Piso*, " 'tis hard to say, "which of the two most abound in *Brasil*. For as the principal poisons here, are "the leaves, flowers, and fruits of the plants *Tangarac* and *Juquer*, each has its "own root for an antidote; and the natives successfully apply the fat and heads "of vipers to venomous wounds, or an artificial preparation of the whole bodies "of the creatures that gave them". Besides, 'tis probable that human art might reduce all such bodies into useful medicines: at least, the advantages already gain'd by a proper management of antimony and quick-silver may encourage us to hope so. Opium is by physicians rank'd among poisons, yet it affords such remedies as they would be sorry to want. Oil of scorpions is not only an antidote for the sting of that creature, but is also good in other cases. To give only one instance more, the root *Mandiboca*, common throughout the *West-Indies*, which tho' of itself it be deadly poison, is one of the most useful things that country produces; for by an easy preparation, it affords not only many populous nations their bread, which from its taste, and colour I judge good; and to some of them no small part of their drink; but an antidote also.

What farther manifests God's goodness to man is, that the creatures not only delight and accommodate, but also serve to instruct him; for nature every where lays lessons before us; which if we disregard, we lose the great benefit design'd to our nobler part, the soul. "We shou'd not, says *St. Austin*, use our eyes, "like brutes, to provide for the belly, not the mind, but as men, to behold "the heavens, and the work of nature, and thence discover their author".

Lastly,

Lastly, the creatures not only demonstrate the being and attributes of God, but likewise remind us of our duty; for God informs us hereof no less by his works, than his word; thus the rain-bow, for instance, was design'd to shew his goodness to all nations, and prevent their expecting a second deluge. 'Twas a truly great saying of *Plato*, "The world is God's epistle to mankind"; for God, accordingly, by *Solomon*, sends the sluggard to learn industry of the ant; and *Christ* commands his disciples to learn prudence and inoffensiveness from serpents and doves; he bids them also consider the lilies of the field, in order to acquire a firm reliance upon God. *St. Paul*, rebuking the *Corinthians* for their weak faith as to the resurrection, bids them reflect on the sowing of corn; and the *Psalmist* grows humble by contemplating the highest works of nature: "When I consider, says he, the heavens the work of thy fingers, the moon and stars which thou hast ordain'd, what is man that thou visitest him"? Hence it appears, that God design'd the world not only as a palace for men to reside in, but also for a school of virtue to bring them to eternal felicity.

S E C T. III.

HAVING shewn how greatly the study of nature promotes both the temporal and spiritual welfare of mankind; let us next consider whether a stop put to natural inquiries would not tend to deprive God of the glory that is due to him. And certainly, we can never praise and admire him for those works which we think it pernicious or dangerous to consider. But the works of God are not like pompous pageants, or the tricks of jugglers, where concealment is requisite to wonder: our admiration always rises here, in proportion to our knowledge; because the farther we contemplate, the more signs we discover of the author's perfection: and even our utmost scrutiny can give us but a faint veneration of his omniscience. For, however obvious his existence appears, it requires a close and philosophical consideration to shew he has display'd in the creatures a power, wisdom and goodness worthy of himself. What different ideas of his wisdom arise from the consideration of eggs to a naturalist, who has traced the cicatrícula to the formation of the chick; and one who only knows their common use? As God therefore, delights to be honoured in all our faculties, and consequently in that of reason, as well as faith, there will appear an immense difference between that general, confused, and indolent idea we usually frame of his power and wisdom, and those distinct, rational and affecting ones of his attributes, which may be gain'd by an attentive inspection of the creatures, that were chiefly made for this very purpose. The queen of *Sheba* had, in her own country, conceived very highly of *Solomon's* wisdom, yet she undertook a journey to become an eye-witness of its effects; and finding them infinitely to surpass what fame had related, confess'd it in a pathetic extacy.

Whether a stop put to natural inquiries would not deprive God of the glory due to him.

Admi-

The Usefulness of Philosophy.

Admirable is the saying of *Hermes Trismegistus* to his son, "There's is no religion more just than to know the things that are, and to return thanks for all things to him that made them. Be pious and religious, O my child, for that is the best and highest philosophy". And, perhaps, our more numerous wants and appetites were design'd to spur us on to scrutinize and ransack nature, that so we might make larger discoveries of the omniscient author, than other creatures.

To illustrate this point the farther, we may remember that philosophers have almost universally consider'd the world as a temple: not only *Plutarch*, *Cicero*, and *Seneca*, but *Philo the Jew* is express to this purpose. As for *Christian* philosophers, it were endless to cite them upon this head; and even the scripture itself uses the same figure of speech. Supposing then, the world to be a temple, I would infer that man is the priest to officiate therein; and consequently bound, as being the head creature here, to return thanks and praises to his maker, both for himself and the whole creation. And surely 'tis very unbecoming, that God's mercy alone, because most beneficial to us, should engross all our thoughts, whilst his power and wisdom, attributes equal to the former, because all of them are infinite, remain neglected; tho' these commanded the adoration both of man and angels, before sin occasion'd the exercise of the other. For my own part, I dare not thus limit my devotion, tho' I would not undervalue the meanest act thereof that stands recommended either by scripture or reason: still I must think that God is acceptably, and, perhaps, more nobly, served by conceiving high, rational and manly notions, with a suitable adoration, of those divine attributes for manifestation whereof this vast fabric was erected.

From hence, methinks 'tis plain, that to hinder the progress of natural knowledge detracts from God's glory as well as obstructs man's felicity. I will, however, go a step farther, to shew that neither reason, scripture, nor experience can countenance such an attempt.

And first, did the author of nature know that the contemplation of his works led to a disbelief of his being and attributes, he wou'd, surely, never have invited and pressed mankind thereto so strongly as we see he does; for besides the solicitations already mention'd, the sabbath seems originally instituted to commemorate the creation, and give men a frequent opportunity to contemplate God in his works. And the primitive *Christians*, accordingly, celebrated as well the creation on the saturday, as the redemption on the sunday; which practice, tho' the western churches have long since dropp'd, is, I am inform'd, still retain'd in many of the eastern. Moreover, whoever shall duly consider the bible, particularly the books of *Job* and the *Psalms*, will find a greater harmony between philosophy and divinity, than our opponents imagine. *St. Paul* tells us, "the invisible things of God, from the creation of the world, are clearly seen; being understood by the things that are made, even his eternal power and god-head". Nay, so far is the study of nature from leading to atheism, that *Job* expressly says, "Ask now the beasts and they will teach thee, and the fowls of the air, and they will tell thee; or speak to the earth and it shall teach thee, and the fishes of the sea shall declare unto thee. Who knoweth not that in all these things the hand of the Lord hath wrought this"? And agreeably hereto, most of the moral

writers

The Usefulness of Philosophy.

71

writers, and such as labour to demonstrate the truth of the christian religion, undertake to prove the being of a God, from the consideration of the universe, and that he is the author thereof.*

But as philosophy, you say, leads men to atheism, by enabling them to account for the phenomena of nature from second causes, it will be hard to shew how, upon this supposition, it can do so; because we are in no wise able to explain all appearances by any principles whatever. And truly, not only the generation of animals remains a mystery, but, even to explain and adjust all the phenomena of that apparently homogeneous body, mercury, has hitherto prov'd so difficult, that, for ought I know, it may still continue insuperable to the industry of ages to come; for even chymical tortures have hitherto forced no confessions from this *Protens*, but what raise almost as many difficulties as they solve.

S E C T. IV.

BESIDES those we have been speaking of, there is another sort of men, who, ^{The Epicurean system, which excludes a deity entirely.} boldly relying on the vulgar philosophy, and their own sufficiency, pretend to exclude a deity out of the world; tho' many points, magisterially taught, and confidently believed among them, are erroneous, and contradictory to the most obvious, as their doctrine is unable to explain the more abstruse, phenomena of nature.

It is observable, that by refusing to ascribe any thing to God, men impose upon themselves in thinking an inquiry pursu'd far enough when they come to the general cause of an appearance, which, tho' more obvious, is no better understood than the other. Thus, if you ask a reason why of all bodies gold alone should sink in quick-silver? they answer, gold being of all bodies the only one, that is specifically heavier than quick-silver, tho' they are, yet this cannot, by the laws of hydrostatics, be supported therein. But were a curious inquirer, not content with this plausible answer, farther to demand the nature and cause of gravity, it would, I fear, be hard to satisfy him.†

D

And

* This has been so very fully and satisfactorily done of late, particularly by means of that noble lecture, founded by Mr. Boyle himself, to defend the christian religion; that the sect of atheists, if ever there was a real one, is entirely vanquish'd and put to silence. Dr. Bentley first happily began to apply the Newtonian system to this purpose, in his admirable Sermons; and to the same institution 'tis we owe Dr. Clarke's *Demonstration of the being and attributes of God*, Mr. Derham's *Physico-theology*, &c.

† This indeed is an hard question, and Sir

Isaac Newton himself is cautious how he answers it. At the close of his *Principia* he tells us, he has not hitherto assign'd the cause of gravity, which is a power, however, that proceeds from a cause reaching even the centres of the sun and planets, without losing it's virtue, and that acts not according to the particles of the surface, like a mechanical cause, but according to the quantity of solid matter in bodies; it's action being every way extended to immense distances, and always decreasing in a duplicate proportion of them. The gravity of bodies towards the sun, he farther says, is compos'd of their gravity

The Usefulness of Philosophy.

And, doubtless, tho' the immediate causes of many effects in nature are easily assignable; yet upon farther inquiring into the causes of those causes, 'till we arrive at the primary ones, we, perhaps, shall find them to depend on such primary affections of the small particles of matter, or such a joint conspiracy of the several parts of the universe, as it would be impossible to account for, without recourse to an intelligent agent. For the followers of *Aristotle* delude both themselves and others, in pretending to assign reasons for abundance of effects. And not to instance in such abstrusities as they refer to sympathy, antipathy, and occult causes; let us take some obvious phenomena, as that of suction, or the *Menses*; the former they ascribe to nature's abhorrence of a vacuum, and the latter to her providence, lest after puberty the body should be overloaded, and fit nutriment be wanting to the fœtus, in gestation: solutions no way satisfactory to a philosophical inquirer; for both of them suppose, either the world to be endow'd with a kind of soul, or that there are intelligent principles in inanimate bodies. Besides these, there are numberless other questions, relating to the parts of human bodies, the causes and cures of diseases, &c. which they often answer by saying, "nature does so and so, because 'tis fit she shou'd"; without ever explaining what they mean by nature, or how inanimate bodies can act for certain ends: they ought, therefore, 'till their own hypothesis is more intelligible, either to cease ascribing to irrational creatures such actions as manifestly proceed from reason and choice; or else to allow, with us, that such creatures perform them by the direction of a wise author of things.

And tho' I must own that some actions, which, perhaps, are peculiar to man, seem inexplicable by mechanical principles; yet, with regard to other effects of nature, we may suppose, that when God determin'd to make this world, he divided the matter he had provided into numberless particles of various figures; which duly rang'd, connected, and thrown into proper motions, regularly exhibit, by the continuance hereof, all the destin'd phenomena of the universe, as well as if each creature employ'd, acted with knowledge and design, or an intelligent Being diffus'd thro' the whole, presid'd over, and directed all the parts, according to the laws originally establish'd. Thus a curious compound engine regularly performs its office, whilst all the component parts thereof, as if animated by a common principle, conspire to accomplish the maker's end.

'Tis in a sense agreeable hereto, that I always use the common phrases in philosophy: as for instance, when I say an heavy body tends to the earth's centre, I don't mean that mathematical point has the power to attract it, but that, either the

gravity towards all its particles, and in going from the sun decreases exactly in a duplicate proportion of the distance to the orbit of *Saturn*, and even the farthest aphelia the comets, if those aphelia are at rest; but the reason of these properties of gravity I could never hitherto, says *Sir Isaac*, deduce from phenomena, and am unwilling to frame hypotheses about them; for whatever is not deduced from phenomena ought to be called an hypothesis and no sort of hypotheses are allow-

able in experimental philosophy, wherein propositions are deduced from phenomena, and made general by induction. Thus the impenetrability, the mobility, the moment of bodies, the laws of motion and gravity were discover'd. And it is enough that gravity has a real existence, and acts according to such laws as we have deliver'd, and that it suffices to produce all the motions of the celestial bodies, and of our sea. See *Newton. Princip. Ed. 2. p. 483, 484.*

magnetical

magnetical effluvia of the earth, the pressure of some subtile matter,* or whatever else be the cause of gravity, so far determines the heavy body downwards, that if all obstacles be remov'd, it will directly fall to the earth's surface. In the same manner the hand of a clock might be said to affect a circular motion, tho' the metal 'tis made of be indifferent to all motion, because the structure of the machine so determines it; and tho' this motion be stopp'd, yet the hand may still be said to have a tendency to the same motion, because, upon removing the obstacle, 'twill proceed therein. Yet do I not reject such current expressions as these " nature

* Mr. Boyle here, and in several other parts of his works, seems to have entertain'd an opinion as to the cause of gravity, and of many abstruse phenomena of nature, like what Sir Isaac Newton hints in the conclusion of his *Principia*, and more fully insists upon in the queries annexed to his optics, of a very subtile matter that pervades all gross bodies, and lies concealed in them, by the force and actions whereof the particles of bodies attract one another at very small distances, and cohere when they come to be contiguous; whereby electrical bodies act at greater distances as well by repelling as attracting such substances as are near them; whereby light is emitted, reflected, refracted, inflected, and gives heat to bodies; and, lastly, whereby sensation is excited and the voluntary actions of animals perform'd. But tho' several experiments and observations of Mr. Boyle seem to infer, or require such an agent; yet, I find not that he imagin'd it so universal, and to have all the properties which are by Sir Isaac Newton ascribed to it. From what particular experiments it's several necessary properties are deducible, is, perhaps, not easy for any one less versed in the phenomena of nature and art than that great philosopher to say; but whoever inquires into the cause of the firm cohesion of the hard component particles of bodies, which are only laid together, and touch but in a few points, will, as Sir Isaac Newton observes, find a necessity of something to attract or press them towards one another. The same thing he also infers from the cohesion of two polish'd marbles in *vacuo*, from the standing of quicksilver in the barometer, at the height of 50, 60, or 70 inches, whenever it is well purged of air, and pour'd in, so that its parts are every way contiguous to one another, and to the glass; for the atmosphere, by its weight, presses the quicksilver into the glass to the height of 29 or 30 inches, and some other agent raises it higher, by making its parts stick to the glass; and to one another; for by any discontinuation of parts made by bubbles, or by shaking the glass, the whole mercury falls down to the height of 29 or 30 inches. The ascent of liquors between

glass or marble plates, and in small glass tubes, either empty, or filled with sifted ashes, which happens as well in *vacuo*, as in open air, are also, instances to this purpose. But farther says Sir Isaac Newton, if in two large tall cylindrical vessels inverted, two little thermometers be suspended so as not to touch the vessels, and these vessels be removed from a cold place into a warm one, the thermometer in *vacuo* will grow warm as much, and almost as soon as the other thermometer which is not in *vacuo*, and when the vessels are carried back into the cold place, the thermometer in *vacuo* will grow cold almost as soon as the other; is not therefore, continues that great author, the heat of the warm room convey'd thro' the vacuum by the vibrations of a much subtile medium than air, which, after the air was withdrawn remain'd in the vacuum? And of this medium or aether he thus queries with regard to gravity. Is it not much rarer within the dense bodies of the sun, stars, planets and comets, than in the empty celestial spaces between them? And in passing from them to great distances doth it not grow denser and denser perpetually, and thereby cause the gravity of these bodies to one another, and of their parts toward the bodies; every body endeavouring to go from the denser parts of the medium towards the rarer? For if this medium be rarer within the sun's body than at his surface, and rarer there than at an hundredth part of an inch from his body, and rarer there than at the fiftieth part of an inch from his body, and rarer there than at the orb of *Saturn*; I see no reason why the increase of density should stop any where. And tho' this increase of density may, at great distances, be exceeding slow, yet if the elastic force of this medium be exceeding great, it may suffice to impel bodies from the denser parts of the medium towards the rarer with all that power which we call gravity. And that the elastic force of this medium is exceeding great, may be gather'd from the swiftness of it's vibrations. &c. See *Newton. Optic. English Edition, A. 1718. p. 323, 325, 326, 364, 372, & alibi passim.*

The Usefulness of Philosophy.

affects the best, "nature does nothing in vain"; &c. for, as according to my own notion, the actions of irrational creatures are directed by a most wise agent; I am not surprized that their actions resemble ours, or even sometimes exceed them. And, in fact, silk-worms and spiders perform, untaught, what we cannot; birds build their nests more dextrously than a man could; and many other animals perform such things, that 'tis no wonder some have ascribed reason to them; tho' this seems rashly done, considering much may be said for the immortality of rational souls; that the actions of brutes are chiefly limited to the preservation of their species; and that they betray a want of thought in every thing besides. And, therefore, as when I see a curious clock, and find every part nicely adapted to its respective end, and all harmoniously joining to answer the views of the artificer, 'tis the contrivance of the workman, not of his materials that I admire; so when I contemplate the several creatures of this vast engine, the world, I can never suppose that the inanimate parts thereof act with reason and design, but adore the wisdom of the architect, who could produce such regular effects from the joint concurrence of so many different causes.

It may here be objected, that tho' the school philosophy fails, yet the *Epicurean* accounts for the production of the world, without having recourse to a deity; but a consideration of the doctrine of *Epicurus*, and his paraphrast *Lucretius*, tho' subtile philosophers, has confirm'd me in the contrary opinion.

Epicurus himself, in his epistle to *Herodotus*, found in *Diogenes Laertius*, gives this short system of his doctrine; "As to meteors, it ought not to be imagin'd that motion, rotation, eclipses, rising and setting of the heavenly bodies, or any thing of this sort happens from the direction of a superintendent, who enjoys happiness and immortality: we are, therefore, to believe that at the creation of the world there happen'd such a convulsion of twining atoms as render'd these revolutions necessary. There is an infinite number of worlds, only some whereof are alike to this; for as atoms, from the infinity of space, must be infinite; they will meet in various places, and so variously constitute infinite worlds far remote from this:" which obscure account of the world's origin *Lucretius* finely illustrates, and afterwards applies it to some particulars thereof. But his hypothesis requires many postulata too absurd or uncertain to be granted; for instance, "that matter is eternal; that it was actually divided into atoms from eternity, (whereas it might as well be one coherent mass; for actual division is in no wise essential thereto); that the number of these atoms is truly infinite; that they have an infinite vacuum to move in; that their figures are almost infinitely various, (tho' he shews not how this came to be conical, or that spherical); and that these atoms were self-moved from eternity," tho' motion be no more an essential property of matter than rest; being perfectly indifferent to either*. Nor has it hitherto been shewn how matter can move itself. Almost

* Motion and rest are in the modern philosophy supposed to be states of bodies; yet some have endeavour'd to prove the former essential to matter. And, indeed, if a thing may be said to be essential where it is a constant attendant; perhaps the dispute is at an end. For all the bodies we are acquainted with, seem to be in a perpetual motion. No one will say that the parts of animals, vegetables, or minerals are at absolute rest among themselves, who considers the growth, increase, decrease, corruptions and changes of them. Mr. Boyle has made it high-

The Usefulness of Philosophy.

21

all the bodies here below are moved by something external to them; even in animals tis not the will that produces spontaneous motion: this only determines and directs the nervous fluids of the muscles, as appears by the fatigue and loss of strength consequent upon violent exercise. And therefore *Anaxagoras*, tho' he believed, as *Aristotle* did after him, the eternity of matter, allow'd a mind was necessary to put it into motion. But in the *Epicurean* scheme, not barely motion, but also it's determination is suppos'd; for the atoms must move downwards, and that too not in parallel but converging lines; so that besides motion, here is gravity in atoms without a centre for them to tend to, and a particular direction and continuance of motion therein, without any cause being assign'd for either; which are assumptions so bold and precarious, that some of the author's admirers are ashamed of them. This doctrine farther supposes, "that allowing a downward motion to a sufficient number of atoms; a fortuitous concurrence in their fall, will, alone, produce the world, with all its creatures;" that is to say, chance may reduce a chaos to order, or a multitude of letters, casually thrown together, give us the history of the creation as it stands in the book of *Genesis*.

'Tis true indeed, odd images, resembling pictures, seem accidentally produced in stones, and other inanimate bodies; but these phenomena are fairly to be solved from other principles: tho' were these allow'd to be real productions of chance, how different are they from what we behold in the structure of animals? To instance, in a human body, which tho' compos'd of numberless parts, none are superfluous, or can be otherwise made or placed without manifest detriment; nay, some of them, as the eye, valves in the veins, &c. are so dextrously adapted to their respective uses, and intirely unfit for any other, that a more than ordinary understanding is required to discover the depth of their contrivance. On the other hand, that account which *Lucretius* gives of the first formation of man, from poetical wombs adhering to the ground, which *Lactantius*, at large, exposes, is so unsuitable to some other parts of his work, that I am tempted to suspect he wrote it in one of those phrenzy-fits his *Lucilla's* philtre occasion'd him.

Let it be farther observ'd, that, with all their assurance, the utmost these naturalists can do, only shews the phenomena of nature may possibly be produced after their manner; but as the same effects often proceed from different causes, it may, sometimes, be impossible to discover by what particular means nature obtains her ends. And even *Epicurus*, himself, never pretended to assign the precise cause of the phenomena he endeavour'd to explain. So that allowing we did, in general, know that the phenomena of nature proceeded from the bulk, figure, motion, &c. of atoms, we may still be to seek for the particular causes of any single effect: thus a man might say, in general, the fam'd clock at *Strasbourg*, mov'd by means of wheels, springs and weights; tho' he knew no-

ly probable that the parts of the most solid bodies, such as glass, gems, &c. are in motion. And 'tis now generally confels'd that the earth, which itself is in perpetual motion, as well as the other planets, and the comets, moves round the

sun; so that in short nothing appears to be at rest in our system but the centre of it; and this, possibly, is constantly going forwards in a strait line. See *Newton. Princip. Ed. 2. p. 17, 18.*

373, 374.

The Usefulness of Philosophy.

thing of their respective magnitudes, figures, motions and proportions, or the particular contrivances of the whole.

But the more eminent *Epicureans* argue thus, “if the phenomena of nature be “not solved by our hypothesis, they are inexplicable”; but this argument is not so conclusive as they seem to imagine. And tho’ it be as bold to assert, as hard to prove, that no other philosophy can do more than theirs; yet, if we allow their conclusion, where’s the absurdity? Who has demonstrated that men are able to find out and explain all the operations of nature? The most learned of our adversaries own themselves unequal to the task.

It adds no strength to their argument, that their way of solving appearances is easy and intelligible; for the question is how things really are produced, not what manner of production is most level to our reason. And if the world, as they say, were casually made, sure, chance never considered of the most intelligible way: but if God be its author, and framed it according to his own immense wisdom, how shall human understanding comprehend the contrivance? And hence we may infer that current argument, “I cannot conceive it” to be of no force in philosophy. Tis true, we should be cautious of admitting unintelligible things for truths; but there is so great a difference in the thinking faculty of men, to say nothing of partiality, indolence, want of application, and wilful dulness, that what is unintelligible to one, ought never, for that reason, to be rejected by another. Thus some *Epicureans*, who would resolve all things by mechanical principles, tell us they can form no notion of an incorporeal substance, or spirit; nor supposing the soul were such, how it could act upon the body; yet others solemnly profess they have a clear and distinct idea of spirit, which they believe the human soul to be; and deny they can comprehend how any thing should think that is material.

Thus much for those who presume to account for all things without supposing a God: others, more modest, who yet incline to this opinion, might propose the following objection. “Tho’ we cannot assign a real cause of every effect in nature, “we take away the necessity of a deity, by shewing, in general, that the phenomena of the universe are mechanically producible”.

To this I answer; first, it does not appear that all the phenomena of nature can be solved by mechanical principles, as particularly the faculties and actions of men; and if a spiritual substance be here allowed, not only a fundamental doctrine of the *Epicureans* “That there is nothing in the universe besides body and vacuum”, is given up, and the possibility of a spiritual superintendent would likewise follow. Secondly, allowing them explicable hereby, tis no consequence that there was originally no need of an intelligent Being to range and dispose a chaos, or infinite number of atoms into a regular world; and to establish those principles whereon the production of numberless creatures depends: for matter, however figured and moved, seems of it self as incapable of doing this, as a quill, when cut into a pen, is unable, of it self, to write. Besides, were an *Epicurean* to be told, that a man, after having been many years dead, came to life again, he would, I presume, reject the relation as of a thing impossible. And why, but because so strange an effect cannot be ascribed to chance? For he knows no power great enough to collect the scattered atoms, whereof, according to him, that body was wholly composed, and so dispose and move them, as again to constitute the same. This example,

ample, indeed, extends not to all the circumstances of the case; but I infer from it, that a considering man may happen confidently to reject what is not absolutely impossible; and that such things may possibly be effected by matter and motion, as no wise man will think produced without the direction of an intelligent agent. Lastly, *Lucretius* affirms, "That the atoms made no agreement to settle into a world," and the very notion of atoms implies them inanimate; so that did we grant all the productions in nature to result therefrom, the difficulty would still recur, what thus ordered and directed them? It must, surely, be as absurd to think that innumerable senseless atoms, as that a few more bulky parts of matter, should jumble themselves into so curious a fabric as that of the universe, or a human body; and consequently, 'tis incredible they cou'd, without the guidance and direction of a governing principle, constitute either.

S E C T. V.

BUT to resume our former subject. Be it true or false that some things in nature tempt a philosophical more than a vulgar mind, to doubt the existence of a deity; without dispute, there are others that persuade the former of it's certainty, more than they do the latter. For many properties of bodies are known to these, many secret relations, and harmonious correspondences between the parts of the universe, which escape a superficial view. So that if, as 'tis supposed, *Aristotle* wrote his discourse concerning the world, towards the end of his life; 'tis remarkable how he, who used to be sceptical enough, rises, by contemplating the universe, to lofty encomiums of it's divine architect. But more particularly, he who is ignorant of anatomy, can never receive those demonstrations of wisdom, from the circulation of the blood, the motion of the chyle, and other contrivances in a human body, which crowd upon an expert anatomist. There are fine mechanical contrivances in the hand, the foetus in the womb, in the muscle, called *Marsupialis*, that serves to move the thigh, and in many other parts of the body. 'Tis not, therefore, surprizing that *Galen*, tho' no great religionist; should, from contemplating the human structure, take occasion to compose hymns to the creator. And methinks, 'tis impossible any man should behold a skilful dissection of an eye, without acknowledging that a good anatomist has stronger reasons to admire the author of nature, than one who is unacquainted with that art. Sure I am, 'tis nothing but our ignorance can hinder us from giving just praise to God for that excellent mansion wherein the soul resides; since not only *David* celebrates him, because, says he, "I am fearfully and wonderfully made"; but anatomical dissections, as we just now observed, raised even *Galen*'s devotions. Yet perhaps, even anatomy it self has not discovered to us all the wond'rous contrivances in the human body; nor ever will, till a competent knowledge of the several animal fluids, of chymistry, mechanics and philosophy, be added to a dextrous manner of dissection. Without some acquaintance with proportions, twill be hard to judge of the symmetry of the parts; as without skill in optics, 'twould be impossible

That a philosopher is by some things persuaded of the existence of God, more than a vulgar mind.

The Usefulness of Philosophy.

to see the wisdom displayed in the structure of the human eye, compared with those of other animals.

Farther, 'tis manifest, from universal experience, that the study of nature leads to the belief, rather than the denial of a supreme Being. The ancient philosophers, who had no revelation, generally acknowledged one; as appears from numerous testimonies: and if ever any real atheists appeared, their number has been inconsiderable, and their patrons always esteem'd as monsters. As for the nations that, at this day, are said to worship no God; they consist not of naturalists, but irrational barbarians, who cannot be said to deny, but to be ignorant of him; and that too, because they know so little of his works. But if there be any such people as these, 'tis a strong recommendation of philosophy; and shews that without the assistance of supposed innate ideas, reason, alone, exercised upon the objects around us, will discover a deity. And indeed, as the stars in their courses were said to fight against *Sisera*; so not only they, but the rest of the creatures, in their courses, fight against atheists.

Philosophy instructs us to admire and celebrate God.

Again, philosophy, not content to prove the existence of a God, instructs us also to admire and celebrate his perfections. The noblest worship has been paid him by the greatest part of the world, where his will was never particularly revealed the temple of the universe sufficed to transport them with rational wonder at the attributes of it's author. And this kind of devotion, commonly rising, in proportion to the discoveries made in nature, the best philosophers among the heathens, always shew'd the most of it. No wonder then, that the *Indian* gymnosophists, the *Persian Magi*, the *Egyptian* sacrificers, and the ancient druids were priests as well as philosophers. And were it not too tedious to give instances wherein the creatures have manifested to philosophers the attributes of God stamped on them, I might have quoted many passages out of both ancient and modern writers, to this purpose. Moreover, were our adversaries position as true as we have shewn it false; why must a philosopher, tho' ever so knowing, needs be an atheist? Philosophy is only one way of coming to the knowledge of a God: religion has other arguments to enforce such a belief. The devils must be well versed in philosophy to instruct magicians and their other dependents, and would gladly, no doubt, bend all their knowledge to propagate atheism; yet St. *James* tells us, "that they themselves believe there is a God, and tremble at him". It follows, that either

The fulfilling of prophecies, and working of miracles demonstrate the being of a God.

Philosophy furnishes arguments against atheism.

philosophy does not, necessarily, lead to atheism, or that other than philosophical arguments may convince the most obstinate of the being of a God. But to leave speculation, and come to fact: the seasonable accomplishment of prophecies and the working of miracles, at once, demonstrate the being, providence and other attributes of God. And as these are the strongest arguments divines can use for the truth of the christian religion, I hope, they will allow the force of them. I say, then, if these arguments prove the truth of the christian religion (and what can do it more effectually?) they consequently prove the existence of a God. *

Lastly, so far is philosophy from leading to atheism, that it furnishes us with arguments against it. The atheists have long presumed themselves the only philosophers,

* With this view it was, that Mr. *Whiston*, in conformity to the founder's design, attempted to shew the accomplishment of the scripture prophecies, when chose to preach Mr. *Boyle's* lecture. He endeavours to make it appear, that none of those prophecies have a double meaning, and that they respectively have, at their due time, been fulfilled.

sophers, and to perplex others with philosophical notions; yet a skilful naturalist will greatly reduce the number of their greatest difficulties, and easily surmount them. Eternity, self-existence, and other attributes are objected by the *Epicureans* against the being of a God; whilst they suppose the origin of local motion, the infinity of space, and the divisibility of matter, which are full as hard to conceive upon their scheme; so that instead of one God, they confess, as we have seen, an infinite number of eternal, self-sufficient, immortal, self-moving atoms; and raise many more difficulties to one accustomed to leave second causes, and contemplate such as have none.

Upon the whole; I am afraid lest the delightfulness of philosophy should too much devote men to the creatures, rather than make them disbelieve a creator; for the beautiful variety of objects here proves so charming, that we sometimes grow negligent of other pleasures, and even of our religious duties. Tho' God being infinitely better than every thing else, he alone can afford mankind their utmost satisfaction, which those deprive themselves of, who rest wholly in the creatures.

But my zeal for philosophy has hurried me too far, and given my discourse a relish of the preacher; yet I have *Seneca* and *Pliny* to bear me out herein: nor, perhaps, is it a fault thus to have treated a subject I should not have engaged in, had I found any thing satisfactory wrote upon it by others. But as divines are commonly too ignorant of nature's works to treat philosophically of them; so naturalists rarely presume to handle them with a view to religion.* I cannot, therefore, but acknowledge, that, if this discourse any way answers the ends I proposed by it, I shall ever esteem it the best part of my works; for I am persuaded, that whoever could bring philosophical devotion into the reputation it deserves, would honour God as much as by erecting buildings for religious uses.

Nor is this kind of veneration, this λογική λατρεία, superseded by christianity; for God by affording us a revelation, cannot have given up his right to us as rational creatures, in which capacity we offer in the world eucharists to it's creator. *Galen* could say that "to manifest the perfections of God to others, is a greater act of religion, than to burn whole hecatombs upon his altars"; which *Hermes Trismegistus* thus confirms "The thanks and praises of men, are the noblest incense that can be offered up to God". And God himself is pleased to tell us, "that he who sacrificeth praise honoureth him"; and again, we learn that an acceptable part of religion is the "sacrifice of praise, and the calves of our lips" by offering up of which we make a true use of the creatures in referring them to the creator's glory; so that as "all things are of him, and through him, they may also be to him".

* This might be a merited reproach when Mr. [this occasion Dr. Bentley, D. Clarke, Mr. Boyle wrote these essays; but it has since been Whiston, Mr. Derham, and others, who have wiped off, by many excellent writers among preached the lectures of our excellent author. the divines. 'Twere needless to name on

PART II.

Shewing the usefulness of natural philosophy to the art of medicine.

S E C T. I.

*Philosophy shou'd
be reduced to
practice.*

HAVING seen the advantages accruing from natural philosophy to the mind of man; let us next consider those it brings to his body and goods. And here, I must own, that this kind of usefulness is what so highly recommends philosophy to me: 'tis the increase of power, not amusing speculations that I expect from it. Nor dare I assume the title of a naturalist, 'till the productions of my garden, orchard, or fields, exceed those of others unacquainted in this study. Wou'd we convince the world of the real usefulness of natural philosophy, we should take a like method with *Thales*; who, 'tis said, being reproached for studying the stars, as a thing of no significance, made all the forehand contracts he cou'd for olives of the ensuing growth; whereby he became immensely rich: for the year, as he had early foreseen, proved very bad for oil, which he, therefore, sold at his own price; and thereby shewed that philosophers rather despise than covet wealth.

Methinks it is a disgrace to a philosopher when he comes to consider the art of husbandry, not to be able, with all his knowledge, to improve the precepts which only illiterate persons have given about it. From the school philosophy, indeed, nothing of this kind is to be expected; but from the true principles of science, thoroughly known and applied, 'tis inconceivable how universal and advantageous a change might be made in the world. What a turn has been given to affairs by those two slight discoveries, the needle's pointing to the north, and the reluctance between salt-peter and brimstone? And what are all the trades in the world, but so many corollaries or applications of a few theorems of natural philosophy?

*The usefulness of
natural philosophy
to the physiological
part of medicine.*

But the more distinctly to shew what improvements may be expected in the several arts, by a due application of natural philosophy thereto; we will divide them into those that relieve our necessities, those that accomodate, and those that delight us. To begin with physic; tho' I pretend not to be a doctor in that faculty, I shall follow the common division of its branches; and briefly observe how each of them is indebted to natural philosophy, or farther improveable by it.

Did I not greatly respect *Hippocrates*, I might say, that some of the bloody laws of *Draco* were less destructive than his single aphorism, "If a pregnant woman be
" let

"let blood she will miscarry". For experience, at length, has assured us of the safety of phlebotomy, even, contrary to his express assertion, when the fœtus is large. But if an error of omission may prove so fatal in physic, what are we to expect from those of commission, and rash proceedings? As the physician must necessarily take his principles from the naturalist; 'tis surprizing that men, esteem'd wise by themselves and others, should condemn the study of nature; because we frequently see those in possession of the greatest worldly happiness, at once deprived of it all, thro' the ignorance, or mistake of the doctor.

Our own age has shewn us what light comparative may give to human anatomy. The advantages of comparative anatomy to physic. 'Twere a savage cruelty to dissect, as did *Herophilus* and *Erisistratus*, human bodies alive; nor could many things, as the motion of the blood and chyle be discover'd in a dead one; it must, therefore, be of use to physicians to see living irrational animals dissected: and thus the lacteal and lymphatic vessels came first to be discover'd. Many experiments, also, may here be made, which it were imprudent to venture upon in the bodies of men. The spleen has been cut out of a dog without any damage; and I lately assisted in the experiment successfully made upon a young setter, that recover'd in a fortnight after the operation. The empiric *Fioravanti*, indeed, says he perform'd it upon a splenetic lady, who lived many years afterwards; but tho' his relation were credited, the situation of the part forbids such an adventurous procedure. To know, that, tho' frogs have lungs and use them as other terrestrial animals, they may, without suffocation, be detain'd for many hours, nay, some days under water, might help to determine the nature of respiration. And, generally, the parts of brutes are so like the corresponding parts in men; that a good acquaintance with the former will, in most cases, render the trouble of obtaining the latter, unnecessary. *Galen*, who is allowed to have been no bad anatomist, rarely dissected any other; for in his time 'twas thought irreligious to put human bodies to such uses. And no wonder, since to this day, the use of anatomy and skeletons is forbid in *Muscovy*; the first, as inhuman; the latter, as serving to witchcraft: and we are told by *Olearius*, that one *Quirin*, a *German* surgeon there, being found with a skeleton, was expell'd the kingdom, and hardly escap'd with life: and the skeleton, after being dragg'd about the streets, was burnt.

There are many other advantages of comparative anatomy, which may serve to confirm any new discoveries, or illustrate the true use of the parts in men; for scarce any creature can be well understood of itself, much less the body of man, without comparing it with those of different animals, to see where any part is omitted, wherein it differs in magnitude, figure, situation, connexion, &c. Thus, on the coast of *Ireland*, I observ'd a kind of fish, about the size of mackrel, whose hearts seem'd to be inverted; their bases lying towards the tail, with the mucro pointing to the head, and adhering to the *Aorta*. The lungs of vipers, and other creatures, their hearts and blood, which are always actually cold, may make us farther inquire, whether the chief use of respiration be to cool the heart.

The sudden and continued collapion of a dog's lungs, discoverable upon a large wound in his chest, may afford some discovery in the principal organ of respiration. The hearts of vipers, and some smaller fishes, where the contraction

The Usefulness of Philosophy.

and relaxation of the fibres may be distinctly observ'd, might help to decide the controversy about the cause and manner of the heart's motion. To satisfy myself in this matter, I have sometimes cut the heart of a flounder transversly, into two parts; and freeing each from the blood it contain'd, I observ'd, for a considerable time, that both of them, together continued their former contraction and relaxation. And once, thus cutting one into several pieces, I found, to my surprize, that they not only moved as before, but that even the whole, thus separated, long preserved the same succession of motion, as appear'd therein whilst coherent.

Questions concerning the use of the heart, and the principal seat of life and sense, may also receive light from this kind of experiments. I remember, that having cut out the heart of a live frog, without closing the wound, he, notwithstanding, leap'd about the room, as if no hurt had been done him; tho' his entrails hung out, and he dragg'd them after him. Upon his resting, we prick'd him, after which he leap'd as before; and being put into water he could swim, whilst his heart remain'd in my hand. We took out the hearts of others more carefully, and sew'd up the wound, whereupon they leap'd more frequently and vigorously than the former; they also swam, and remain'd in water, as if all their parts were intire; sometimes they would nimbly leap, first out of the vessel, and then about the room; in short, some survived the extraction of their hearts an hour, and others longer. These creatures, notwithstanding, cannot survive the loss of their brain. To proceed to warm animals. I observed the heart of a chick unhatch'd, but perfectly form'd, to beat for above an hour after the head and breast bone were clipp'd off to disclose it; but the auricles retain'd their motion longer; tho' that of the other parts disappear'd in a few moments after the head was off. The heart, when dead to appearance, was often, by puncture, excited to fresh motion of short continuance. This experiment we repeated with the same effect; but when the motion of the heart, and its auricles became languid, 'twas again excited by placing them in the steam of hot water; by which contrivance we kept the heart beating for an hour and half. At another time, we, by the like method, continued the motion of that of a larger chick for two hours and an half. But this is nothing to the strange vivacity we have observ'd in that cold animal the viper; for not only their heart, tho' sever'd from their bodies, will beat for several hours; but the body itself will continue to twine and twist for some days after the skin, heart, head and entrails are taken from it; and upon puncture, especially near the spinal marrow, will manifest a vivid motion, after they have long lain quiet. And tho' *Indian* tortoises are very large animals; *Vincent le Blanc* tells us, "when the king of *Pegu*, an admirer of them, design'd any for his table, their heads were cut off five days before they were dress'd; to the end of which time they, notwithstanding, continue alive". To these might be added the common observations of flies, butter-flies, and other insects, surviving the loss of their heads; and not only so, but as I lately found in butter-flies, that they are capable of procreation afterwards. I shall not pretend to draw any certain conclusions from hence; but 'tis sufficient to my purpose, that such kind of experiments have relation to the doctrine of the unceasing influence, of the brain, suppos'd requisite to sense and motion.

That

That the colour of the blood is owing to that of the liver, seems not improbable from the livers in men; but in hens eggs, after the third or fourth day of incubation, the *punctum saliens*, or heart, is found full of very red blood before the naked eye can discern a liver, at least any redness therein. And in large fish I have found the vessels of the liver full of red blood, tho its substance were white.

That the loss of a limb is irreparable has been unanimously believed, yet the common case of lizards, lobsters, craw-fish*, and, perhaps, some other animals, does not confirm it absolutely true. The tails of lizards have, after being struck off, been found to grow again. Credible persons have inform'd me of their observing the same in lobsters claws; and I, myself, have known it in those of craw-fish.

An acid in the stomach has, of late, been supposed the cause of digestion; but in the stomachs of several ravenous sea-fish, my tast could discover no such thing; tho' we found, in one of them, two other fishes that measured each a foot in length, whereof that which seem'd latest devour'd, had suffer'd very little alteration, whilst all the external parts, except the head, of the other, were uniformly wasted, or corroded, far below the original surface of its body. Indeed, by a menstrum drawn from vitriol, as also by oil of vitriol, I have dissolv'd roasted flesh into a kind of red or purple gelly, or liquor; and this without the assistance of heat. Thus then it appears that the naturalist may greatly assist the physician in his anatomical inquiries.

But besides these particulars, the naturalist may also instruct the physician how to preserve the several parts of human bodies, or other animals. For as the structure, connexion, &c. of the less common parts in anatomy, like the alteration of plants in botany, are apt to slip out of the memory; it may be refresh'd by judicious preparations in the one, no less than by a proper collection of specimens in the other. We find, by experience, that butter-flies, and other insects, long retain their shape and colours, by being left properly transfix'd with pins on the inside of boxes. Reflecting once, how long spiders, flies, and other animals, have been preserved by an accidental inclosure in amber; I was induced to try the like expedient with clear *Venice* turpentine: by evaporating which to about two thirds, I obtain'd a reddish transparent gum, clear of bubbles, easily soluble by heat, and as easily render'd brittle by cold.

How to preserve the parts of animal bodies for anatomical purposes.

* M. *Reaumur* has publish'd some curious remarks which he made upon these animals. He tells us, that several parts of them will grow again as well as their claws; that their large claws or legs accidentally break near the fourth articulation, reckoning from the tip, and then gradually grow out again to the former dimensions; that if one of these large legs be purposely broke at the fourth or fifth articulation, 'twill come again, but either not at all, or not so well, when broke at the first, second, or third articulation, if it were to be left thus; but

that in a few days time the creature itself, probably, breaks the claw higher about the fourth joint, for it is then found broken thus; after which the re-production goes forwards. He farther assures us, that if a part re-produced be broke off a second time it will, nevertheless, grow again. But the summer, which is the only time wherein craw-fish feed, favours these new productions much more than any any other season. *Memoir. de l' Acad. A. 1712. p. 295-321.*

When

The Usefulness of Philosophy.

When I design it for use, I melt it, being first pulverized, with a gentle heat, and dip the body to be preserv'd several times therein, 'till it gains a case of due thickness. This substance, indeed, is inferior to amber, being more apt to gather dust; but care may prevent that, and then its cheapness will recommend it.

Nor are only smaller bodies capable of this treatment. The external parts of more bulky ones, as those of birds, fishes, crocodiles, and horses are found preserv'd in repositories; and many anatomists can easily keep the internal membranous parts uncorrupted. I have seen the veins, arteries, and nerves of a human body thus display'd in their proper situation, upon boards; as also the parts of generation, which continued for many years to be far more instructive than a printed figure of them. And I have known the flesh of vipers kept good for several years, by the smoak of an aromatic powder. The skeleton of a monkey has been shewn me, with the muscles rais'd, and curiously preserv'd upon it. And, perhaps, some way may be found to keep the arteries and veins plump after they are emptied of blood. A very fluid matter, which would soon harden, might do this; such as the liquid plaister of burnt alabaster; the gelly of ising-glass, or sugar of lead, frequently dissolv'd in spirit of vinegar. To proceed, I have known a foetus long preserv'd in oil of spike; and a large one, managed in a different manner, appear'd to me, after many years, as entire, plump, and fresh as if it were newly dead*. 'Tis possible, some nobler way than what has hitherto been practis'd may, hereafter, be found out; for I suspect that saline, corrosive, or hot bodies are not the only ones which strongly resist putrefaction; and that embalming substances may be effectually applied without mangling the body. *Josephus Acofta* relates, that "men, and the beasts they ride on, are sometimes, on certain mountains of *America*, kill'd by the winds; which, alone, afterwards preserve them from "putrefaction". I am acquainted with an experienced gentleman, fam'd for curing cancer'd breasts, by the external application of an innocent powder: and musk, to my knowledge, has greatly contributed to the preservation of flesh.

'Twere also proper to try how far spirit of wine would contribute to preserve a human body; for tho' it strongly resists putrefaction, it does not fret the flesh; nor will its colour disguise the objects therein contain'd. And I, myself, have, for many months, preserv'd in it very soft parts of a body, without any detriment to their figure or consistence; at another time we, for a long while, kept a large quantity of blood surprizingly sweet and fresh, by mixing it herewith; nay, by means of it, we even prevented a piece of a very stale fish, from farther putrefaction. I have also open'd eggs at several days after the beginning of their incubation; and taking out the chicks, embalm'd each

* The ingenious *Ruysh* seems to have advanc'd the art of injecting and preserving the parts of animals to the greatest imaginable degree of perfection. The injection he performs by means of instruments finer than the threads of a cobweb, as, in his late epistle to the learned *Boerhaave*, he expressly declares; so that he says he offers no violence to the vessels, nor, when he pleases, distends them beyond their natural dimensions. By this means, and by some particular way of preserving of them afterwards, he has, as it were, re-animated dead bodies.

The Usefulness of Philosophy.

31

of them in a distinct glass of spirit of wine carefully stopp'd. When the chick was large, I have sometimes mix'd with the spirit of wine a little spirit of sal-armoniac, made with quick-lime; for tho' this abounds with an urinous salt, yet I never observ'd it to coagulate spirit of wine. And I usually found it convenient to let the little animals first lie, for a while, in common spirit of wine, to wash off the looser filth; and then having put better upon the same bird, I suffer'd it to soak, for some time, therein; that the liquor having, as it were, drawn what tincture it could, the subject being remov'd into more pure and highly rectified spirit of wine, might not discolour it. And by this means, also, I preserv'd the head of a monstrous calf; wherein, tho' the body of the animal seem'd otherwise perfect, there was no sign of a nose in the usual place; the two eyes being united into one, in the middle of the brow, and furnish'd with but one large optic nerve. The sclerotic containing both was single, but seem'd to have a seam, by which the eyes were join'd, that went quite round; the pellucid part being distinctly separated from the two cornea's; each seeming to have its iris and pupil distinct. Upon opening the cornea there appear'd two crystal-line humors. There were four eye-brows in the head. Just above the eyes was a deep cavity, out of the middle whereof grew a kind of double purse, which seem'd a production design'd for the nose. Nor is it hard to improve the balsamic virtue of this spirit.

From hence it appears possible that human industry may, hereafter, discover such ways of preparing animal bodies, as will greatly improve anatomical knowledge. But the body consisting of fluid, as well as solid parts, gives another opportunity to the naturalist of improving medicine; by shewing not only the difference between solidity and fluidity; but also by examining into the nature of several animal juices, with the alterations both they, and the aliments they are made of, undergo in their several stages. For, since the human body appears to be only a curious machine; a naturalist well versed in chymistry and machines, may, doubtless give some new light into it's phenomena.

S E C T. II.

THAT natural philosophy may assist the physician to discover the nature and causes of diseases appears from hence, that tho' the similitude between a human body and the world, be not so great as *Paracelsus* imagin'd; yet the same phenomena often happen in both, but more conspicuously in the latter; which must, therefore, illustrate those of the former.

The advantages of natural philosophy to pathology.

And certainly, if a physician know not how heat and cold, fluidity and firmness, fermentation, putrefaction, viscosity, coagulation, dissolution, &c. are generated and destroy'd in most bodies, he will be at a great loss, when he comes to find out the causes of diseases; for many of them entirely depend upon the presence, absence, or change of these and the like qualities. On the other hand, 'tis a

A knowledge of the properties of bodies, and the phenomena of art and nature useful to a physician.

The Usefulness of Philosophy

fine advantage to have learnt, by a variety of experiments, the different ways whereby nature sometimes produces the same effects ; for several solutions of the same appearances may hence arise, which, otherwise, might never have been dreamt of. This, surely, is no small advantage to a physician ; since he, who is only acquainted with a few of nature's ways of procedure, is unlikely to know how abundance of diseases are produc'd ; and, consequently, will sometimes mistake the cause, and apply remedies accordingly ; when the poor patient, perhaps, must dearly pay for his physician's ignorance. He, who knows nothing of the origin and growth of stones out of the body, is unable to explain their production in the bladder and kidneys. Many famous physicians, we find, have suppos'd them generated from slime baked to a hardness by the heat of the part ; and, accordingly, directed for cure, remedies to moisten and cool the kidneys. This notion could hardly have obtain'd but from the ignorance of the ways of petrification in other cases ; for a liquor may turn wood into stone ; give to other bodies hardness and weight ; and even produce crystals in cold water : nay, in such cold aquatic animals as craw-fish, strong concretions are generated otherwise than this hypothesis supposes ; for those bodies, falsely call'd crabs eyes, are, at certain times of the year, taken out of their heads. And the *ossa alba* of *Paracelsus*, produc'd upon a due mixture of spirit of urine and spirit of wine, is a different kind of concretion, serving to illustrate the same.

That an earthy substance may lurk undiscern'd in a limpid liquor, appears from wine, which throws off to the sides of the containing vessel a solid tartar ; clear common urine, also, affords a sediment, and if distill'd before it ferments, leaves an earthy portion, and commonly some gravel behind. Nay, rectify'd spirit of urine will, upon long standing, let fall a precipitate, and throw a multitude of small concretions to the sides of the containing glass, like those that are found in urinals. By barely mixing two distill'd and transparent liquors together, I have often immediately obtain'd a blackish, dry, and brittle coagulation : and by this means *Helmont* attempts to account for the generation of the stone in human bodies. And tho' none of these ways be, of themselves, satisfactory, 'tis something to give a probable account of this distemper, which seems more difficult and abstruse than several others. So that not only philosophy, but chymistry also, may contribute to clear up the nature of some diseases.

The *Galenic* physicians usually account for catarrhs, by comparing the stomach to a boiling pot, and the head to an alembic, wherein the vapours being condens'd by the coldness of the brain, distil upon the lungs, or other adjacent parts ; which hypothesis, however insufficient, manifests, that chymical operations may illustrate the doctrine of diseases. And since the fluids of the body abound in saline and sulphureous parts ; he who understands the nature of salts and sulphurs, their actions upon each other, as well as different bodies, seems better qualify'd to discourse rationally about their changes and operations, than one who ignorant is herein. To know that acid juices may lodge in the stomach, and elsewhere ; that the serum is coagulated by heat ; that the blood abounds in volatile and sulphureous, but manifests no acid salts ; that animal salts and spirits, as spirit of urine, or that of harts-horn, are able to make a red solution with the flowers of sulphur ; that spirit of urine, or of human blood, will soon make a blue

one with crude copper; to know the consistence, smell, crackling, and other qualities of the lymphæ, when exposed to the fire; how acid liquors lose their acidity by working upon some bodies, as vinegar upon coral; and how saline ones degenerate into salts of another nature by working upon others, as oil of vitriol upon quick-silver; how acid and sulphureous salts, sometimes disarm, sometimes, after ebullition, precipitate each other, and sometimes unite into a third substance, of a nature different from either, as the vitriolated tartar; in a word, to have made numerous careful trials upon the human body, as well as other productions of nature, and to have applied the observations made on the latter, to illustrate those of the former, more enables a man to explain several particulars in pathology, than an ignorance of these things.

The chymists, methinks, speak too slightly of the humours of the body, and allow them too little share in the production of diseases; for the relations of *Skenkian*, and other eminent physicians, as to the corrosiveness of some animal juices, rejected by urine or vomit; which, they say, would ferment on brass, fret linen, and tarnish silver; incline me to believe that too much has formerly been ascribed to the humours, as hot and dry, cold and moist, and too little to the saline and sulphureous properties of them. And *Hippocrates* seems to confirm this opinion. " 'Tis not, says he, cold or heat, moisture or dryness, that produce so great effects as bitter and salt, sweet and acid; insipid and sharp; " when they come to be unduly mixed, and when any of them predominate." And were these juices chymically examined by one who knows how to volatilize fix'd bodies, and to fix volatile ones; 'tis probable, many things relating to the nature of the humours, and the ways of sweetening, sharpening, and otherwise altering them, with the importance of such an alteration, may be discovered. Nor might it be unserviceable to extend this examination to the noxious juices of distempered bodies; as the phlegm expectorated from unsound lungs, the slimy excretions in a lenter, or the fluid that distends the abdomen in a dropsy; which latter I found of a different nature from either water or urine; for it would keep long without putrefying; and upon evaporation over a gentle fire, when fresh, it first grew ropy, then fizy, and at last glutinous.

Thus, in order to examine the stone of the human bladder, I carefully opened two that had been cut out by a lithotomist, and found each of them to consist of several coats, that successively involved each other, like those of an onion: and the same I since observed in a large stone taken out of an ox's gall. They were nearly as hard as common stones, tho' they differed from each other therein. In one of them we found an intermediate coat, differing in colour from the two contiguous ones. Some of the coats were the length of a barley-corn in thickness; and tho' they closely adhered to each other, they were actually as well as visibly separable. In the center of one of them, we found a small soft oval stone, so loose that we picked it out, and preserved it as a rarity. After this, they were finely powdered, and put into a small glass retort, strongly coated; and luting a receiver thereto, two ounces and a half, the whole weight of the stones, being distilled for some hours in a naked fire, afforded a large quantity of volatile salt, and a reddish spirit, which in the receiver coagulated into salt. Upon separating the vessels, we found, in the neck of the receiver, a little dark-coloured oil, but much

Stones found in the human bladder, chymically examined.

The Usefulness of Philosophy.

more in the neck of the retort, incorporated with a good deal of volatile salt, of a scent and a taste not unlike those of the salt of unfermented urine. The *Caput mortuum*, a light coal-black powder, appeared like fine soot, and weighed about six drams; which shewed that above two thirds of the stones, being volatile, had, in a close vessel, been forced by distillation from the terrestrial parts thereof; while the *Caput mortuum* remained fixed enough to give a suspicion that it contained a heavy oil: calcining it, therefore, we reduced it to about two drams of an insipid white calx; which did not fall asunder, like lime, when cast into water.

Substances of a mineral nature found in human bodies.

From this example it should seem no great error in the followers of *Paracelsus*, to say that arsenical, vitriolic, aluminous, and other mineral-like substances, are generated in human bodies. We find stony concretions not only in the bodies of men, but of sucking children. The heat, it is true, is not violent here; but why should that alone be supposed the efficient of all the changes our aliment undergoes, when there are dissolvents, ferments, strainers, and other powerful agents successively working upon it? A very eminent person told me that in the fits of an odd distemper, she sometimes vomited up so sharp and fretting a matter, that it burnt her throat, in its passage, like scalding water; stained the silver vessels it was received in, and even worked upon them like a corrosive menstruum. And an intelligent gentleman, also, lately complained to me, that in the fits of a strange distemper he laboured under, he frequently observed that part of his pillow along which his breath passed, was thereby blacked over, as if it had been held in the smoke of a fire.

We might here observe, that the same water which in passing thro' a vine or an apricot tree, becomes sweet fruit, in the lemon or barberry-tree is converted into a liquor able to corrode pearl and coral, like spirit of vitriol. Nay, credible writers affirm, that a certain *Indian* fruit will immediately corrode and waste the steel instrument 'tis cut with, if its juice remain upon it; as we see some of our apples and pears will soon black the blades of knives. I have caused a *Ranunculus* to increase considerably in weight and bulk, by allowing its root nothing but fair water. And as this plant is reckoned poisonous, and when externally applied, capable of raising blisters; why may not such aliment as contains many parts more active than water, receive from several concurring causes such an alteration in a human body, as to render it like fossil salts, or other minerals? Do we not see cancers, ulcers, and sharp humours generated in the body, destructively imitate the operations of arsenic and corrosive salts? The infusion of antimony hardly more stimulates nature to disburthen her self by the mouth and *Anus*, than doth sometimes a fretting humour; as that which causes the *Cholera morbus*, or other more violent distempers.

And that aliments should thus degenerate in distempered bodies, is less strange than that water should be changed into an hot vesicatory substance; tho' to lessen the wonder, I can say, that from a single pound of common bread, I have obtained many ounces of a menstruum, which will operate upon bodies more compact than solid minerals, or glass itself; and that too more strongly than could be expected from *Aqua fortis*. These things are mentioned to intimate how chymical experiments might be usefully applied to illustrate pathology, either

ther by imitating, artificially, such kinds of morbid matter as are sometimes found in the body; or by resolving that which is therein generated, to discover it's nature. Not that I think chymical experiments alone sufficient to explain the doctrine of digestion, or diseases; it would be difficult from hence to shew how nutrition is performed; or how the feeding only on vegetables should plentifully stock the blood and urine with a volatile sulphureous salt; for plants don't yield it by distillation. Much harder would it be from chymical principles to account for the hereditary propagation of diseases; or to shew how madness, and some other distempers, which appear not visibly to affect the organs, whose functions they pervert, should not only prove hereditary, but lurk for many years in the body, before they manifest themselves; and sometimes descend from grand-father to grand-child, skipping the intermediate son. I say, therefore, that vulgar chymistry cannot solve all the pathological phenomena, tho' the true kind may assist in many cases; and some seem inexplicable without it. Let me add, that a thorough knowledge of the nature of ferments and fermentations would, probably, conduce to the solution of many phenomena of diseases, which, perhaps, will never be understood by any other means. There may, 'tis true, be effervescencies, and, perhaps, periodically, in the blood and other juices, without a proper fermentation. For as, at the decline of coughs, the phlegm no longer strongly adheres to the vessels of the lungs; so other humours, either by growing more fluid, or the blood becoming fitter to dissolve them, may circulate herewith, and thereby occasion preternatural heats; whether thro' an indisposition to incorporate with it, by altering it's texture, disturbing it's motion, preventing it's due rarification, obstructing the finer canals, causing extravasations, or any other means. * Experiment has shewn there are liquors wherewith if milk, oil, or even water be mixed, a remarkable heat will immediately ensue. And I have made use of a menstruum, wherein flesh will, in a few minutes, excite an heat scarce tolerable to him who holds the containing glass in hands. Nor is this the effect of a true fermentation, but rather of the disturbed motion of the particles of the menstruum; wherein the nature of heat seems chiefly to consist.

But a naturalist may not only thus illustrate pathology as a chymist, but also as an anatomist. The dissection of sound brutes may promote the discovery of the corresponding parts in human bodies; and the anatomy of morbid beasts often gives light as to the seats and causes of diseases in men. 'Tis certain, pathology has been greatly improved by the diligence of the moderns in dissecting of morbid human bodies, and thereby discovering the seat and effects of the peccant matter that proved destructive. And the knowledge gained hereby may be augmented or illustrated by making the like observations on brutes. Thus, by a chymical analysis of the blood of sheep, deer, &c. it's phlegm, spirit, salt, and oil are found very like those obtained from human blood; and in the bodies of several other animals, worms, imposthumes, and the like, seem manifestly to arise from the same causes, they do in us. And 'tis very remarkable that considerable quantities of grass have been found in the *Aspera arteria*

Anatomy tends
to advance patho-
logy.

* Bellini deduces the causes and symptoms of fevers from a lentor of the blood, tho' what that lentor is, he nowhere, that I remember, fully declares. This passage may, therefore, serve as an explanation of that term; and Bellini's whole doctrine of fevers, may well be consider'd as a comment upon this useful hint.

The Usefulness of Philosophy.

of cattle, when they were opened; and chyle in the veins of men. 'Twas thro' want of such knowledge that *Helmont* asserted the stone to be a disease peculiar to man. There are also diseases, for the cause whereof, the compression, obstruction or irritation of some nerve, the distension of some vein, or an obstructed circulation of the blood in some part, are assigned; in which cases we may safely venture to make an experiment in brutes thus affected, in order to shew the truth or falshood of the supposition, and establish a just method of cure.

An hemiplegia, occasion'd by a small splinter of a bone pressing upon the dura mater.

A very tall and well set gentleman, aged about 24 years, had his skull broken in several places, by a fall from his horse; and being a person of a good estate, several chirurgeons attended him in the course of his sickness; during which, he was several times trepann'd, and had several pieces of his skull taken off, which left great chasms, as I have seen, between the remaining parts. Within about three days after his fall, this gentleman was seized with a dead palsy on his right side, tho' it did not equally affect his arm and leg; the use of the latter being sometimes suddenly restor'd to him in some measure, and after a while almost as suddenly lost: but his arm and head were constantly paralytical, being wholly deprived of motion; his arm having so little sense, that it would sometimes lye under his body without his feeling it. But if his hand were prick'd with a pin, he could take notice of it. This palsy continued during almost the whole time of the cure, which lasted 24 weeks. And when the chirurgeons were going to close up his head, as having no more to do; one of them who was an ingenious man, opposed all the rest, alledging, that, if they did no more, the gentleman would lead an useless and very melancholy life; and that he was confident, the palsy was some way or other occasion'd by the fall, which had left something in the head that they had not yet discover'd. And the gentleman himself agreeing to the motion, his head was further laid open; and at length, under a piece of proud flesh, they found, with much ado, a splinter of a bone, that bore hard upon the *dura mater*, and was not pull'd away without a great hemorrhage, and such a stretch of the parts, as made the patient think his brain it self was tearing out. But this was soon remedied, and his wound securely heal'd up; and he is now a strong healthy man, and finds no inconvenience by having so broad and various a *Callus* instead of the skull; except that he is a little liable to take cold in his head. But the memorable circumstances, for the sake of which I mention this history, were these. 1 The bone last taken out was less than half the nail of ones finger, and almost as thin; being in size and shape like the scale of a fish; tho' it did not in his head lye flat, but bore hard upon the *dura mater*. 2 He, in less than five hours after this bone was taken out, found himself able to move his little finger; and (tho this happen'd in the evening) he was the next morning able to move all his fingers, and within two or three days after, to lift up his arm: by which it seem'd manifest, that so little a body as the splinter, produc'd, in so robust a person, a palsy of the whole side it lay on. For he found no relief till the bone was pull'd out, that is till long after the chirurgeons had been by degrees eating off the proud flesh that grew about it. 3 Remembring the important controversy among modern physicians and anatomists, about nutrition by the nerves, I inquired whether he did not find a wasting in the limbs of his body that were affected? He told me, that

when

when he began to be paralytic, the side affected, greatly wasted by degrees, and that the paralytic leg was very much extenuated; but the arm and hand much more; seeming nothing but a system of bones, with the skin pasted on them; that upon the removal of the bony splinter, the consumption of the parts also began to lessen; and that in no very long time, his leg and arm recover'd their proper dimensions. And I lately saw the restor'd arm well plump'd up with musculous flesh, tho' the weather were exceeding cold. He further told me, that he found no difference between the limbs that had been paralytic, and the others; except that they would grow sooner, and more sensibly cold in sharp or frosty weather.

This gentleman assured me that during the course of his cure, he was almost every second day let blood; that he wanted not an appetite; that for the most part, he slept indifferently; and lastly, that upon so great a hurt, he did not vomit, nor had afterwards any convulsions.

To proceed, there is a whole class of diseases produced by poisons, towards obtaining a knowledge whereof, experiments upon brutes might greatly conduce; for altho' some things may be poisonous to man, that are not so to other animals, & *vice versa*; yet, as the greatest number of poisons affect both equally, the exhibition of them to brutes will afford good opportunities for observing their effects. Thus a dog, I remember, bore a quantity of opium sufficient to kill several men; and a cat run mad upon having a large dose of it given her.

I am convinced by experiments, that vipers are poisonous only by their bite, when enraged *; and that the immediate application and continuance of a hot iron to the wound they then make, will prevent the ill consequence thereof. Experiments to be made upon brutes, to acquaint us with poisons and their antidotes.

This I myself tried in a man, who, for a reward, provoked a black viper, and suffered himself to be bitten by it; upon which the injured part instantly swelled: but having applied a heated knife as near the wound as he could endure it, for 10 or 12 minutes, the swelling did not increase, and the man received no farther harm. † I could wish more experiments were made about poisons, to determine whether their operations appear'd more sudden by being receiv'd at the mouth; by being applied externally; or by wounding particular vessels with instruments dipt therein. For, I remember to have seen some *Indian* poisons, whose noxious efficacy was affirm'd to appear at different distances of time, and to prove differently mortal, according as the arrow infected therewith open'd a capillary or a larger vein; or wounded a part that lay near or remote from the heart. This, indeed, I have not tried, so don't depend upon. *Olearius* also, in his travels, tells us of a venomous insect in *Persia*, by the natives called *Encureck*, which he supposes a

* The poison consists in an actual liquor, contain'd in peculiar bags, which in about the quantity of a drop, is forcibly immitted in the bite. This venomous liquor view'd thro' a microscope appears to be a parcel of small rigid salts briskly floating in a fluid, which when extravasated, soon shoots into crystals, incredibly small and sharp; with something like little knots up and down therein. See *Mead of Poisons*, p. 9.

† But this remedy failed *M. Charas*, and is not so certain as the viper-fat, rubb'd into the wound soon after it is received. Dr. *Mead* successfully made the experiment with it twice; upon dogs; and 'tis the principal thing whereon the viper-catchers rely, when they are bitten. See *Mead's Essays on Poisons*. Ed. 2. p. 27, 30. For more experiments made with vipers. See *Philos. Transact.* No. 87. p. 50, 60.

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Inquiries for the transfusion of the blood of animals.

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The Usefulness of Philosophy.

by being quite new stocked with the blood of a cowardly dog, may not become more tame, and *vice versa*.

Whether immediately upon unbinding a dog, replenished with adventitious blood, he will know and fawn upon his master; and do the like customary things as before? And whether he will do such things better or worse, sometime after the operation.

Whether the peculiarities of dogs, will either be abolished, or impaired by transfusion? As whether the blood of a mastiff, being frequently transfused into a blood-hound, or a spaniel, will not prejudice them in point of scent?

Whether acquired habits will be destroyed or impaired by this experiment? As whether a dog taught to fetch and carry, to set, &c will, after frequent and full recruits of the blood of dogs, unfit for those exercises, be as good at them as before?

was found very thick and greatly concreted; but so unequally that much of the serum seem'd uncoagulated. A thick grumous matter fill'd the ventricles of the heart, almost like a polypus; black blood stagnated in the lungs, and a part, being extravasated, adhered to some of the lobes thereof. The same spirit of vitriol, being injected into a dog, which a little before had taken two ounces of liquid laudanum, turned his blood exceeding liquid, part of which was just before let out from a vein, grumous.

9. A little dog having by injection received into his jugular vein two scruples of *Saccharum Saturni*, dissolved in half an ounce of the decoction of pomegranate shells; the motion of his heart presently began to languish; his respiration became hard and difficult; and convulsions seizing him, he died in five minutes. The jugular and iliac veins being opened, blood issued out thereof, that was partly fluid, and partly grumous and thick concreted, something like an oil floating upon it, which in taste resembled *Saccharum Saturni*. The blood in the aorta was so concreted that it was almost fibrous. The lungs were full of coagulated blood, and in some places inflamed. The blood in the heart was so concreted that it seem'd to grow to the pillars of it's ventricles.

10. Half a dram of dragon's blood, dissolved in warm water, being, at twice, injected into the jugular vein of a large dog; the motion of his heart, and his respiration were more frequent, and afterwards, without any ill symptom, he suddenly fell down dead. Soon after, the muscles of his thorax were so convulsed, that they appeared both the tight and touch alternately to contract and relax themselves. The jugular vein being opened towards the head, a frothy blood came out almost one half whereof was clotred. That in the iliac vein was wholly concreted into a solid mass; some small portions of it appearing as compact as if the cavity of the vein had been injected full of wax. The

small vessels which run thro' the external coat of the kidneys, were very visible: the lungs appeared turn'd with concreted blood; and the heart was greatly distended with some, that, in the right ventricle, was as thick as gelly; but more so in the left.

11 Two ounces of vinegar, thrown into the jugular vein of a dog, only caused his heart to beat more frequent; two ounces more made his respiration difficult and troublesome; but this went off upon letting out a large quantity of blood, which appeared somewhat clotted, from the iliac artery. The same dose being again injected, the dog expired. A very thick massy blood came from the iliac vein when opened; in the other veins, and in the arteries, 'twas lightly concreted; but in the heart, and especially in the left ventricle thereof, some part of it was strongly coagulated.

12. Half an ounce of *Spir. Salis Dulc.* injected, after the same manner, into another dog; his respiration thereby became strong and high; but by degrees it sunk so fast, that the dog died before the injection was finished. The blood appeared greatly concreted in all the veins and arteries. The lungs were inflamed. The heart filled, and, as it were distended with blood; so that four ounces were taken from the right ventricle, corc.eted like a gelly. In the left there was little, but strongly coagulated; and in the aorta 'twas like a polypus.

13. Half a dram of salt of steel, dissolved in two ounces of water, and injected into the jugular vein of a dog, gave him a palpitation of the heart, and a very great difficulty of respiration; upon which he died. The blood in the iliac vein was not concreted, but a little clotred. In the heart and aorta it was somewhat coagulated, but less than in other experiments. *Freind Emmenolog.* p. 167, 171. 180-183. For more experiments of this kind, made upon arterial and venal blood, and upon the serum. See *Piscarn, Element. Med.* p. 28-33.

Whether any considerable change is to be observed in the pulse, the urine, or other excrement of the receiving animal, or in the quantity of his insensible transpiration?

Whether, the other dog being full fed at such a distance of time before the operation, that the mass of blood may be supposed to abound with chyle, the receiving dog, being hungry before, will lose his appetite, more than if the emit- tent dog's blood had not been so chylous? And how long, upon opening a vein of a dog, the admitted blood will be found to retain chyle?

Whether a dog may be kept alive without eating, by frequently injecting the chyle of another, taken freshly from the receptacle, into the veins?

Whether a dog that is sick of some disease, chiefly imputed to the mass of blood, may be cured by exchanging it for that of a sound dog? And whether a sound dog, may receive such diseases from the blood of a sick dog, as are not otherwise of an infectious nature?

What will be the effect of frequently stocking an old and feeble dog with the blood of young ones, as to liveliness, dulness, drowsiness, &c.

Whether a small young dog, by being often fresh stocked with the blood of a young dog of a larger kind, will grow bigger than the ordinary size of his own kind?

Whether any medicated liquors may be injected, together with the blood, into a dog? And in case they may, whether there will be any considerable difference found, between the separations made on this occasion, and those, which would be made, if such medicated liquors had been injected, with some other vehicle, or alone, or taken in at the mouth?

Whether a purging medicine given to the other dog, a while before the operation, the receiving dog will be thereby purged, and how?

Whether the operation may be successfully practised, in case the injected blood be that of an animal of another species, as of a calf into a dog, &c. and of a cold animal, as of a fish, frog, or tortoise, into the vessels of a hot animal, and *vice versa*?

Whether the colour of the hair or feathers of the receiving animal, by the frequently repeating this operation, will be changed into that of the other?

Whether by frequently transfusing into the same dog, the blood of some animal of another species, something further and more tending to a degree of change of species, may be effected, at least in similar animals, as spaniels and setting dogs, *Irish* grey-hounds, and ordinary grey-hounds, &c?

Whether the transfusion may be practised upon pregnant bitches, at least at certain times of their gravitation? And what effect will it have upon the whelps? *

* From several experiments of the transfusion of the blood, mentioned in the *Philosophical Transactions*, it appears, that the blood of young creatures, admitted into old ones, makes them, as it were, young again. And the principal advantage hitherto gained by such experiments is the know-

ledge that one animal may live with the blood of another; and that those animals, which want blood, or have it distempered, may be supplied with a sufficient quantity of such as is good from other animals.

S E C T. III.

The advantages
of natural philoso-
phy to the semeioti-
cal part of medi-
cine.

THO the semeiotical part of physic seems less capable than any of receiving improvements from natural philosophy; yet by giving light to anatomy and pathology, 'twill enable a physician the better to form a judgment upon the constitutions of his patients, and the symptoms of their diseases. For certainly, to be acquainted with the solids and fluids of the body, is the best qualification for this purpose. A naturalist, also, by improving the curative part of medicine, may alter the duration, severity, and event of distempers; for the common predictions of physicians are built upon the present establish'd remedies, and a dogmatical method of cure: whereas, if generous and powerful medicines were discover'd, they need not so often, in acute cases, wait for a crisis to instruct them; * and the threatening symptoms of chronical distempers would frequently prove fallacious.

The Peruvian
bark recommended
for agues.

When the *Peruvian* bark was scarce heard of among us, I recommended it to several of my friends afflicted with quartans, in the most unfavourable season of the year; and under such disadvantageous circumstances that their physicians only hopes depended upon better conjunctures; yet, to the surprize of them all, it never failed. Some, indeed, suffered relapses, but they were again relieved by repeating the medicine; so that many eminent physicians, moved by these examples, gave into the use of it, and were never deceived thereby. † And granting relapses do happen, yet it is very serviceable to procure a respite, wherein a physician may have recourse to other remedies; tho' the bark is every way sufficient in a prudent hand that knows how to assist it by gentle purgatives. ‡ I cannot, therefore, but wonder it has never been tried in other diseases; for 'tis highly probable that a medicine able to prevail against so obstinate a distemper as a quartan, wherein many of the most considerable parts of the body are affected, should be ineffectual in others. § But whether this remedy expels the morbid matter, or alters

* This is an useful hint to physicians: to wait for a crisis is leaving the distemper to it self; to promote it is determining the fate of the patient the sooner; but to prevent it, where this can be done with safety, is the thing we ought principally to endeavour.

† 'Tis a curious observation of *Dr. Freind*, that physicians unjustly complain of the uncertain effects of remedies; and that the fault they attribute to the medicine, is in truth, their own. For he shews that the different operation of remedies arises not from a change of virtue in the medicament, which continues always the same, but from the different state of the body wherein it is applied. The action of the former, says he, is ever similar to it self; tho' according to the different disposition of the body, it may seem to produce different, and, perhaps, contrary effects. Thus the same fire will soften some things and harden others, by acting in the same manner; and

a fever if the blood be thin, will raise the pulse, but depress it, if that be thick: steel, if the vessels will suffer a farther distention, opens obstructions, but increases them if the vessels will yield no more: emetics prove cathartic if the stomach be strong; and cathartics prove emetic if that be weak: sudorifics thin the blood, but do not promote sweat, unless the cuticular glands be free and open, &c. See *Emmenolog.* p. 148-155.

‡ This method is now generally practised with happy success; and we are obliged to *Mr. Boyle* for setting it on foot.

§ *Mr. Boyle* is often an excellent guide to physicians, and recommends nothing to them without reason. This advice, also, has been happily put in practice; and the bark is successfully used as a stomachic, anaststringent, a strengthener, a cordial, &c. and still seems applicable to many other purposes.

it's texture so as to render it harmless; or whether it afterwards secretly produces any noxious effects in the body, must be a work of time to discover. * In the mean while, if *Riverius* has not flatter'd his *Febrifugum*, there will be no want of a safe remedy for quartan agues.

To proceed, as stubborn a disease as is that of the king's-evil, we have known it cured, as we said above, by a slight and easy remedy. I might add, that an experienced chymist, has promised to shew me a way of making very uncommon, yet rational predictions, in some abstruse diseases, by examining the patient's urine. But as some chymists have written extravagantly upon a like subject; and as I have not hitherto seen the experiment, I dare not offer this as an instance of what I am endeavouring to shew. But 'tis not altogether improbable that by precipitation, and other unusual ways of examining the urine, made by the same patient, at several times, before, during, and after some great alteration in the body; many discoveries, particularly in acute diseases, may be made, especially if other excrements of the same patient be at the same time chymically examin'd.

That question, concerning the curableness of all diseases, might easily be determin'd, by observing 'tis one thing to ask, "whether all diseases be curable", and a different one "whether all persons are recoverable"; for a disease may be incurable, either in it's own nature, or by accident; that is, either 'tis incurable in every patient, or the circumstances of a patient may render it so. No follower of *Paracelsus* wou'd affirm every disease to be curable in every patient; nor would a moderate *Galenist* assert that the gout, the dropsy, and the stone, are universally incurable.

Too many diseases esteemed incurable.

'Tis true, I cannot but condemn the vain-glory of *Paracelsus*, and his followers; yet I think mankind obliged to the chymists for giving us hopes of performing greater cures than were before their trials attempted. For, till the world was awaken'd, by many promises, and some great performances of *Arnoldus de Villa nova*, *Paracelsus*, *Rulandus*, *Severinus*, and *Helmont*, physicians made very free with the word incurable; and wou'd rather detract from nature and art, than confess that both, in conjunction, cou'd perform more than ordinary medicines. And, I fear, there are still too many, who, tho' they will not openly say certain diseases are incurable; yet would undervalue, if not deride him, who shou'd attempt to cure patients afflicted with them. So that I am apt to think many men have been suffered to die, whose lives might have been saved, wou'd physicians have attempted to save them. 'Twere, therefore, doing no small service to mankind to make a collection of the cures of such persons as have recovered after being pronounced incurable by the doctors, to prevent them, for the future, from fathering their own ignorance upon the weakness of nature; and pretending to the world that the art of physic must fail with their skill. Nor shou'd the cures of nature be omitted in such a catalogue, because they shew what may, possibly, be done by natural means, to evacuate the morbid matter, or change it's nature; or else how far the tone of a part, or strength of the body, may be vitiated or impair'd.

* It has hitherto proved a safe and admirable medicine, in prudent hands; and is still a noble specific in intermitting fevers without leaving any dregs, or ill effects behind it, as was long the out-cry against it.

The Usefulness of Philosophy.

whilst it remains capable of some restitution. Dr. *Harvey* told me, that “a patient of his was perfectly cur’d of a confirm’d cataract, by the use of physic, that promis’d no such effect”. The learned *Petronius* also mentions “a venereal patient, who, having formerly lost the sight of one eye by a cataract, recover’d it by the use of the mercurial unctions prescribed him for his other distemper”. And Mr. *Holtyer*, the lithotomist, gave me an account of “a maid who had so far lost the sense of feeling in the external parts of her body, yet without any diminution of their motion; that, tho’ he designedly pinn’d her handkerchief to her bare neck, she would walk about with it, so fix’d, unsensible of what had been done. But continuing, (added he,) a long time in the hospital, uncur’d; Dr. *Harvey*, out of curiosity, visited her; and, suspecting the case to be hysterical, advised her parents to marry her; which being done, she was, according to his prediction, reliev’d from that strange distemper”.

That, in acute diseases, persons given over by physicians may recover, none will deny. *Celsus*, himself, says, “it ought to be observ’d, in acute cases, that the signs of life and death are very fallacious”; and *Hippocrates*, that master in prognostics, allows them to be uncertain; whence the *French* proverb, “it’s better to be sentenc’d by the doctor, than the judge”. Nay, even in chronical diseases, where events usually better answer the physician’s prognostics; there are, sometimes, such cures perform’d, as may encourage human industry, and prevent a sick man’s friends from deserting him, while any life remains. For it not only frequently happens, that persons given over by some physicians, are cured, perhaps more fortunately than skilfully, by others; but those whom judicious and experienc’d men have despair’d of, thro’ the suppos’d incurableness of their disease, rather than their personal condition, have been recover’d by powerful remedies. And of some such cures I am, myself, a witness. Among other accounts I have receiv’d of the cures of cancers, perform’d by Dr. *Harberfeld*, physician to the king of *Bohemia*, I cannot omit, that upon an *English* woman, above sixty years old, whom, after having long lain in an hospital in *Zealand*, with a cancer’d breast, he perfectly cur’d thereof, in the space of six weeks, by one single internal remedy. This relation was made me by persons of great veracity; the one a physician, an eye-witness of the cure; the other a child of *Cornelius Drebell*, who not only saw the cure, but knew the woman before that time, and was the person who brought her to the doctor. The same persons inform’d me, that the medicine was a chymical liquor, which being given, about a spoonful or two for a dose, work’d suddenly and briskly, by vomit; so that its operation ended within an hour, or less, after it was taken. Some of it they presented me with; and finding it to taste like vitriol, I suspect that to be its chief ingredient. They farther assured me, that having obtain’d of the Dr. a large quantity of this specific, they had therewith, both in *England*, and elsewhere, perform’d surprizing cures in the king’s-evil. And an eminent gentleman of this nation, now alive and healthy, was cured thereby; tho’ the king’s evil had brought his arm to that condition, that the chirurgeons appointed the time for its amputation. And, by the internal use.

use of the same liquor, they profess themselves to have cur'd many external and inveterate ulcers. But these are rather surgical than physical cures.

The sad prognostics physicians usually make of dropsies, particularly the *Ascites*, are too frequently verified, when they only prescribe common medicines. I remember a happy cure of this distemper, perform'd by a *German* physician, of whom I had heard a great commendation in *Holland*. I found him, in many respects, a modest man; and tho' he durst not promise to cure so formidable a disease, he acknowledg'd himself possess'd of one remedy which had never, hitherto, fail'd him; tho' try'd upon persons of different ages, sexes, and constitutions. And as incurable as the radicated gout is imagin'd, especially in intemperate persons; yet I knew an honest merchant of *Amsterdam*, who, after being so long tormented with it, both in his hands and feet, that his fits would confine him a great part of the year, and not leave him without hard knots in his joints, was cured with a very few doses of a powder and tincture, not only of his pains, but gouty nodes; and tho' he indulg'd himself the free use of *Rhenish* wine, he has never had a fit since that time, which is ten or twelve years ago, as himself assured me.

How far a skill in chymistry*; and other parts of philosophy, may assist to discover more able remedies than are yet current among us, might be shewn in many other instances; but I chuse to insist upon that of the stone in the bladder.

The Stone in the kidneys and bladder dissolvable.

* Chymistry, as it has of late been cultivated, appears no less serviceable in philosophy than physic. And 'tis surprizing to see how Sir *Isaac Newton* applies it to the noblest purposes in nature. Dr. *Freind*, in his chymical lectures, has undertaken to give a mechanical account of the principal operations of this art. To which end, he lays it down, by way of postulatam, that all similar bodies are in a triplicate ratio of their homologous sides; and if of the same density, that their weights are as the cubes, but their surfaces, as the squares of their diameters; that the moments of bodies are in a ratio, compounded of their quantity of matter and velocity; that if a body be specifically heavier than a fluid wherein it is immersed, it descends with a force answerable to it's excess of gravity; but if lighter than the fluid, it ascends, with the force whereby it's gravity is exceeded by that of the fluid; that there is an attractive power in all the parts of matter which diffuses itself but to small distances; being strongest at the point of contact, and decreasing in more than a duplicate ratio of the distances; that this power differs with the various texture and density of the particles, and is greater on one side of the same particle than on the other; that the smaller the particles are, they approach each other with the greater velocity; and, lastly, that the force, by which parti-

cles cohere among themselves, proceeds from attraction, and is variously changed, according to their various degrees of contact. By means of these *Lemmata*, which are proved by geometrical writers, and, particularly, by Sir *Isaac Newton* and Dr. *Keil*, he attempts to solve the phenomena first of calcination, distillation, and sublimation, which he supposes to be analytical operations; and secondly, of fermentation, digestion, extraction, precipitation, and crystallization, which he treats as synthetical. In the first place, then the Dr. supposes that liquifaction happens whilst the fiery corpuscles insinuate themselves between the particles of bodies, and disjoin them, so that they touch each other in fewer points than before; as appears from the rarification of the body dissolv'd: and from the different cohesion of the parts of bodies he deduces, all the variety that happens in liquifaction. Calcination, says the Dr. is the effect of liquifaction continued; wherein the more volatile corpuscles fly off; and the particles of the fire enter the body in such plenty, and intimately mix themselves therewith, that it can no longer appear in the form of a fluid; and hence, says he, the weight of the calcin'd body is increased. And vitrification, according to him, is no more than a greater degree of calcination; as common glass is made by a long continued fusion, which throws off the lighter

The Usefulness of Philosophy.

der. For tho' it be almost universally pronounc'd incurable, I remember the famous *Monardes*, treating of the seed of a *Peruvian* plant, call'd *Chalchoos*, tells us, 'tis highly esteem'd by the inhabitants of the country, wherein it grows, not only for a diuretic but a lithontriptic, "of which, says he, they produce "so many instances, that I cannot but wonder at it". And the learned Dr. *Gerard Boot* had a famous remedy for the stone, wherewith, as he told me, he had frequently cur'd it in the kidneys; but that in the bladder he thought impossible to be dissolv'd: yet a little before his death, he acknowledged he had then lately done it to one Mr. *Moulin*; and that too by his constant medicine, the distill'd water of arsmart, which he accidentally learnt from a country gentleman, who had cur'd great numbers therewith.

Being some years since in *Ireland*, I met with an ancient empiric, famous for cutting for the stone in the bladder; who having given some good proofs of his skill where I happen'd to be, I consulted him upon a suspicion I long had of a stone in my bladder; but he, upon search, assur'd me there was none; as I afterwards found it. I then asked him, if he had any dissolvent for the stone; he answer'd, he cou'd cure no man of a confirm'd stone, without the help of his knife; but as for lumps of gravel, not firmly cemented, he had an internal remedy, by which, with a particular way of crushing them with his fingers from without, he cou'd render them voidable by urine. And by this means, he said, he had cur'd a citizen of *Cork* of a large stone; which, upon inquiry, I found to be true; and therefore purchas'd his receipt.

Cardan relates, that in his time there travell'd a man over *Lombardy*, who, by a certain liquor, safely, speedily, and certainly cur'd the stone in the bladder: and *Laurembergius* has told the world how he cur'd himself of the same by *Millepedes*, &c. And, indeed, the best arguments that are brought to shew

lighter, and more drossy particles: hence the gravity of the glass exceeds that of the materials whereof it is compos'd. Secondly, the Dr. ascribes the ascent of fluids, in distillation, to their diminish'd weight, by means of rarification; and the impulse of the fire; which acting with great velocity, may raise very heavy particles. Whence the time of elevation, in bodies distill'd, is in a compound proportion, of their rarification and specific gravity. Thus spirit of wine, of sal-armoniac, &c. being specifically lighter, and more susceptible of rarification, ascend easier by the same heat, in distillation, than common water: as acid spirits, which are heavier than that, require a longer time to carry them into the receiver. The increased surface of the rarified particles will, also, greatly contribute to their ascent in distillation, because this exposes them the more, to the action of the fire. Thirdly, the impelling force of the fire, is, according to the Dr. the principal cause of the elevation of the parts of solid bodies in sublimation. Fourthly, the Dr. defines fermentation to be an intestine motion of the parts of bodies, arising from solids dis-

solving in a liquor, or menstruum; and this operation he divides into dissolution and ebullition. Dissolution happens, says he, if the corpuscles of the body to be dissolv'd, attract the particles of the fluid, more strongly than they attract one another; in the mean time, the included air, being rarified, breaks out, and causes an ebullition, and the motion increasing, a heat ensues. Fifthly, the Dr. accounts for digestion, in the same manner, by the attraction of the particles; only, that in this, there is heat made use of. Sixthly, he says, that precipitation, arises, if a liquor of a less specific gravity being pour'd into a menstruum of a greater, lessens the gravity and tenacity of its parts, so as to let the particles, which are now specifically heavier than the fluid, fall down; or when the particles of a liquor, specifically heavier than the menstruum, carry down with them, when pour'd into it, all the solid particles floating therein, which now lie at the bottom; being specifically heavier than the menstruum. In the last place, the Dr. tells us, that crystallization is immediately and entirely perform'd by the attraction of the saline particles concern'd.

The Usefulness of Philosophy.

47

the stone to be incurable, without cutting, seem inconclusive. If appeal be made to numerous fruitless attempts, the preceding experiments may be oppos'd: besides which, *Horatius Augenius* tells us, " he cur'd a youth at *Rome*, who " was going to be cut for this distemper; and likewise, that the *Jesuit*, who " confess'd him, persuaded him to use *Millepedes*; having experienc'd their efficacy both upon himself and others": and, indeed, I have found them to be highly diuretic and aperitive.

If it be objected, that medicines must lose their virtue before they can reach the bladder; I grant this is commonly true: yet some medicines do retain their nature after many alterations and digestions; as turpentine, asparagus, and rhubarb, manifestly affect the urine. Again, if it be said, tho' a liquor were found capable of dissolving the stone, 'twill be so corrosive as to fret the intestines or bladder; I answer, that vinegar will dissolve crabs-eyes, which like the stones we are speaking of, are form'd in animal bodies; and even the more solid body of coral. The bare juice of lemons and barbaries readily dissolves both pearl and coral. What *Paracelsus* and *Helmont*, indeed, relate of their *Alkabeft*, wherewith they prepared their specific against the stone, and pretended to reduce all stones, minerals, &c. into insipid water; I require farther evidence for before I believe: yet a chymist, who often advis'd with me about preparing this liquor, prosecuted the business so far as to bring me a liquor I was surpriz'd at; for it not only dissolv'd common sulphur, and brought it over the helm; but reduc'd antimony into sweet crystals, with a few whereof, to the astonishment of many, Dr. C. without purge or vomit, cur'd Sir C. C. of a very radicated and desperate disease. To the second part of the objection it may be replied; did we know and consider well, how many operations of natural bodies depend upon the suitableness and difference of the figures of their parts, and the pores interspersed between them; the number of impossibilities would not appear so great as they now do.

That it is very possible for one body to act upon another, without acting, in like manner, upon different bodies, seemingly more expos'd to that action, appears from the load-stone, which attracts iron, and not wood or straw. And to come nearer our case; quick-silver, that will not corrode the skin, nor affect the tongue with pungency, readily dissolves the compact body of gold, which even *Aqua fortis*, that corrodes all metals besides, will not touch; and yet quick-silver will not dissolve iron, whilst *Aqua fortis* instantly frets it asunder*. So that, tho' I dare not believe all that's affirm'd by the chymists,

as

* As to the manner wherein metals are dissolved by a menstruum, hear the great Sir *Isaac Newton*. " When *Aqua fortis*, says he, or spirit " of vitriol, pour'd upon filings of iron, dissolves " the filings with a great heat and ebullition; is " not this heat effected by a violent motion of " the parts, and does not that motion argue, that " the acid parts of the liquor rush towards the " parts of the metal with violence, and run forcibly into it's pores, 'till they get between it's

" outmost particles, and the main mass of the " metal, and surrounding those particles, loosen " them from the main mass, and set them at " liberty to float off into the fluid? And when " the acid particles, which, alone, would distil " with an easy heat, will not separate from the " particles of the metal, without a very violent " heat, does not this confirm the attraction between them? ———— When *Aqua fortis* dissolves silver, and not gold, and *Aqua regia* dissolves

The Usefulness of Philosophy.

as to their having made, or seen, insipid dissolvents of gold, silver, and other compact bodies; because I have hitherto been unable to procure them; yet many things that I have not only read, but heard and seen, keep me from positively denying their possibility. And who knows but that art or nature may afford a liquor whose parts shall be adapted to the pores of a human calculus, as those of quick-silver are to the pores of gold; whilst its operation upon the body is no greater than that of quick-silver upon iron? Steep an egg in strong vinegar, for some days, and the external shell will be eaten away, whilst the thin skin, contiguous to the white of it, remains entire; the operations of dissolvents must, therefore, be determin'd by the textures of the bodies whereto they are applied: so that a liquor incapable of corroding a hard and solid body, may be unable to penetrate a soft and thin one, of a texture unfit to admit the particles of the menstruum. Another thing that encourages me in this opinion, is, the relation of *Sennertus*, who tells us, that in the year 1632, "his friend Dr. *Nester* inform'd him, there then lived in his neighbourhood, a man of *Lorain*, call'd *Claudius*, about 58 years old, who frequently devour'd coals, bones, wood, stones, glass, metals, &c. and even the most filthy things that could be offer'd him; of which, says the Dr. among many others, I was an eye-witness". *Sennertus* adds, "that not hearing of this *Claudius* for some time, he sent to inquire what was become of him, when the Dr. return'd a letter from the minister of the place, to confirm the first account; himself declaring the man, whom he had long hoped to dissect, was yet alive, and continued to devour all things as formerly; tho' his teeth being now blunted, he did it, less frequently". More examples of this kind we meet with in writers of good credit: *Columbus*, particularly, records one of a glass-eater, mention'd, also, by *Sennertus*. And, not long since, there was, here in *England*, a private soldier very famous for digesting stones; with whom a curious person purposely convers'd for a day together; during which he observ'd him to eat nothing but pretty large stones; and found his excrement chiefly consisted of a sandy substance, as if the stones he devour'd had been dissolv'd in his body. These cases, surely, prove, that a menstruum not so corrosive as to fret the body, may dissolve stones, and other compact substances. But if a liquor, prepared by nature only, can, in a human stomach, dissolve that great variety of bodies above-mention'd; why may not a menstruum, produced by assisting and heightning nature to the utmost, be capable of dissolving substances of different textures? It must, indeed, be acknowledged, that such common menstrea as dissolve one body, will oftentimes not meddle with another; which may proceed rather from our want of skill to prepare the most powerful menstruum, than any impossibility in the thing; so that

" solves gold, and not silver, may it not be said " that <i>Aqua fortis</i> is subtle enough to penetrate " gold, as well as silver, but wants the attractive " force to give it entrance; and that <i>Aqua regia</i> " is subtle enough to penetrate silver, as well as " gold, but wants the attractive force to give it	" entrance? For <i>Aqua regia</i> is nothing else than " <i>Aqua fortis</i> mixed with some spirit of salt, or " with sal. armoniac; and even common salt dis- " solved in <i>Aqua fortis</i>, enables the menstruum " to dissolve gold, tho' the salt be a gross body." <i>Newton. Optic. p. 352. 358.</i>
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I don't see why a menstruum may not be obtain'd whose variety of parts, figures, and motions, might gain it admission into different bodies. Thus, tho' *Aqua regia* dissolves gold, but not silver, and *Aqua fortis* dissolves silver, but not gold; yet quick-silver will dissolve both gold and silver, copper, tin, and lead.*

And because this supposition, that penetrating menstrea are proportionably corrosive, is apt to stop the inquiries of judicious men, I can assure them, that from common household-bread, as was formerly hinted, I have, by a gentle heat, obtain'd a spirit, which, when rectified, would operate on the hardest bodies so far, as in a short time and without fire, to extract a strong tincture from coral, blood-stone, unpowder'd granats, and, even, the hardest of bodies next to diamonds, rubies. And that these high tinctures did not proceed from a change of colour in the menstruum, I convinced myself by observing that it would, from some minerals, force a deeper colour than from others; and that, when kept separate, it continued clear and limpid for many months.

But it may be farther objected, that "what dissolves the stone in the bladder of one man, may not do the same in that of another"; I reply, this has never been proved; and were it true, as the specifics for agues, fluxes, and the like, are justly prized, tho' their effects be not equally strong in all patients; 'twill be worth knowing that the stone is not, in it's own nature, an incurable disease: and it would well reward any man's industry to relieve even a few from it's torture.

This distemper I the rather chose to insist upon, because 'tis generally thought absolutely incurable by internal remedies, in any subject whatever: but having dwelt too long upon it, I defer considering the dropsy, and some others that commonly stand in the catalogue of incurable diseases. I shall only add, that altho' *Helmont* and *Paracelsus*, by the shortness of their own lives, seem to give testimony against themselves; yet they certainly invented some extraordinary medicines; such, for instance, were their laudanums: yet none of them were comparable to the preparations of *Butler*. This man, as *Helmont* relates, "had a small stone, which being slightly plung'd into oil, or almond-milk, communicated such a sanative virtue thereto, that a spoonful of the former cur'd a *Franciscan Friar* of a dangerous erysipelas in the arm, in the space of an hour; and one drop of the latter applied, in his presence, to a woman's head, immediately reliev'd her from an intolerable *Hemicrania*; and tho' she had been for sixteen years afflicted therewith, it return'd not, to his knowledge, in several years". He adds almost as strange a cure perform'd, in one night's time, upon a servant of his wife, by anointing the part affected, with four drops of the same oil. Nay farther, he tells

Butler's Stone.

* 'Twill, according to the late Mr. *Hauksbee*, by no means account for the suspension of heavy solid bodies in lighter fluids, that the solid gains a large quantity of surface, by being divided into minute parts therein; which is the common way of accounting for this phenomenon. For he found, by experiments, that the difference between an ounce of solid glass, and the same quantity reduced to fine powder; be-

tween a square inch of sheet-brass, and 225 square inches, that is, an equal weight of tinsel *lanias*, weigh'd in water, is vastly too small for this purpose. He, therefore, concludes, that the sustentation of metals, and other substances, heavier *in specie* than the fluids, which dissolve them, are kept floating therein by the principle of attraction. *Hauksbee's Experiments*; p. 231-236.

The Usefulness of Philosophy.

us, "that the master of the glass-house at *Antwerp*, being grown enormously "fast, was soon reduced to a moderate size, by nimbly licking, with the tip "of his tongue, a small fragment of the stone, once every morning". To these he subjoins other strange stories, which tho' I cannot believe, yet circumstances will not let me reject. A gentleman in *France* was reported to possess some portion of this stone, and to have cured many inveterate diseases, by suffering the patients to lick it; and my friend, Sir *Kenelm Digby*, who was then in that country, could not, upon inquiry, find this report to be fabulous. Besides, *Helmont* not only relates these cures as an eye-witness, but says, that once suspecting the virtue of this oil, he anointed it on the right arm and ancles of his wife, who had, for many months, been afflicted with severe pains in the former, and very great tumours in the latter; whereupon motion was immediately restored to her arm; all the swelling of her legs and feet disappear'd; and she continued healthful for nineteen years afterwards. And this relation, she herself, long after the death of her husband, confirm'd to our friend Dr. C. These particulars receive confirmation from two remarkable circumstances: for first, *Helmont* is the more to be credited here, because he mentions cures not perform'd by himself, but by a second person, and that too, with remedies unknown to him; secondly, our famous countryman, Dr. *Higgins*, who lived familiarly in the same house with *Butler*, gives a strange attestation to his secrets.

But whatever be thought of *Helmont's* relations, we have reason enough to conclude, that the power of nature and art may reach much farther than many distrustful, not to say, indolent men have imagin'd; and, therefore, the prognostics, even of celebrated writers, are not to be relied on, when they assert that particular diseases, or particular patients, are absolutely incurable. The solid advice of that judicious author *Celsus*, deserves a greater regard: "where a "medicine fails, says he, we are to respect the patient more than him that invent'd it; and so proceed to try, first, one thing, then another."

S E C T. IV.

*The advantages of
natural philosophy
to the hygienical
part of physic.*

THAT the dectetical part of physic is improveable by natural philosophy, appears in that our aliment requires art to direct its preparation, and order it to the best advantage. The inhabitants of *Barbadoes*, *St. Christophers*, and other *Charribbe* islands, supply us with remarkable instances hereof; where the poisonous root *Mandihoca* is converted, as was formerly said, into both bread and drink: being carefully freed of its moisture by the press, dry'd in the sun, and reduced into meal, it makes the former; and, by being chew'd, and spit out into water, it soon purges itself of its noxious quality, and becomes the latter.

They

The Usefulness of Philosophy.

51

They having in some of our *American* plantations, found it very difficult to make good malt of maiz or *Indian* corn, they first reduce it to bread, and afterwards brew a very good drink from it. And 'tis my opinion, that the malster's art is capable of great improvements among ourselves.

The different liquors of different nations.

'Tis not in the knowledge of fermenting liquors, alone, that we are defective, but also of the materials wherewith they may be made. In *China*, they make their wine from barley; in the northern parts thereof, from rice and apples; but in the southern parts, of rice only. The wine used by the common people will intoxicate, tho' faintly: 'tis made at any season of the year, but best in the winter. In *Japan*, also they prepare a strong wine from rice. We in *England*, likewise, have great variety of wines from cherries, apples, pears, &c. little inferior to those of foreign growth. But to manifest our want of curiosity in this affair, 'tis observable that the drinks of one country are often unknown in another. The rice-wine of *China* and *Japan* is no where to be found in *Europe*; and beer or ale are esteem'd great rarities in places where I have travell'd. The common drink in many parts of *Muscovy*, and other northern regions, is hydromel, or water fermented with honey; and if a due proportion of these ingredients be observed, and the fermentation be skilfully order'd, such a clear, strong, wholesom liquor may hence be prepared, as is not easily credited. In *Brazil*, and elsewhere, they make a strong wine of water and sugar: and in *Barbadoes* they have many liquors unknown to us. Among the *Turks*, where wine of the grape is forbid by their law, the *Jews* and *Christians* keep, in their taverns, a liquor made of fermented raisins. And I my self, by fermenting raisins and water, in due quantities, without yeast, tartar, or any thing of like kind, have frequently, in few days, prepared a good vinous liquor, which afforded, by distillation, a large quantity of inflammable spirit.

I have sometimes wonder'd, that men have so little curiosity to try what liquors are obtainable by wounding trees and other vegetables. The *Sura* in the *East-Indies* is made of the juice that flows from the cocoa-tree; and sailors have often been inebriated, in that country, with the liquors made of the fermented juices obtain'd by the incision of vegetables. And that also in *Europe*, the nutritious juices of trees, as drawn from the earth, receive great alteration before they come to be assimilated, appears from the practice of the *Calabrians* and *Apulians*, who, between *March* and *November*, obtain, by incision, from the common ash-tree, a sweet juice so like the manna, in that season adhering to the leaves of the same kind of trees, that they call it *Manna del corpo*, trunk-manna; and use it successfully. That this sweetness proceeds not from the peculiar nature of the soil, appears in that 'tis also to be found in other places. To proceed: in some northern countries, the liquor that weeps out of the birch-tree is used as a preservative against the stone; for which purpose *Helmont* highly extols a drink prepared thereof, with daucus seeds and brook-lime. But the extraordinary effects I have seen of the liquor itself in this case, and that when other remedies fail'd, occasions me usually to provide a quantity of it every spring. It may easily be preserv'd by pouring oil on the top of it, or by distillation; tho' the best way is to impregnate it with the fume of sulphur. I should not be thus particular upon liquors, but that I suspect, if a greater variety was made, and more skill used in

The Usefulness of Philosophy.

their management, they might, by recruiting the spirits, and insensibly altering the mass of blood, easily prevent and cure almost as many diseases as our common sophisticated wines occasion. For, in fermentation, the active and spirituous particles of vegetables being set loose, and much better separated from the grosser, than by common distillation; they are incorporated with our aliment, and immediately convey'd, by the blood, to those parts of the body, where their operation is required. Talking, one day, with a very learn'd and experienc'd physician about the nephritic virtue of wild carrot-seed; he told me, with a smile, that fermented in small ale, he found its effect too great; for that he seldom heard of those patients more to whom he had once prescribed it.

But to lessen our wonder at the efficacy of fermented liquors, we may consider what virtue is ascribed to a bare infusion of tea; which among the *Chinese* and *Japanese*, is the ordinary drink of persons of quality; who value it so highly, that a single pound of the *Japan* sort is often sold for an hundred pounds of silver: and no wonder, if it preserves them from the stone and gout. I have been told, that, somewhere in the *East-Indies*, they make a drink of the raw flesh of goats, capons, and the like; which, with rice and molosses, they add to a quantity of water, and distil, in an alembic, to a low spirit, call'd *Arrac*, which they frequently drink in hot weather, and find very cordial. Such a liquor, indeed, seems necessary to those of that climate, in order to recruit their spirits, exhausted by the excessive heat thereof; as the merchants travelling thro' the scorching deserts of *Arabia*, *Persia*, or *Turky*, find it best to quench their thirst with brandy, or the strongest *Persian* or *Spanish* wine. The necessity of such a practice is also confirm'd by the concurrent testimony of such of our own nation, as have travell'd in hot countries.

*The preservation
of aliment.*

Not only our liquors are improveable by natural philosophy, but likewise the other parts of our aliment: it teaches us to make better bread than is commonly used, and discovers a better art of cookery than *Apicius* left us; that of pleasing the palat without prejudice to health. Men, unassisted by philosophy, have gone far in preserving food by excluding the air; which daily experience inform'd 'em contributed to its putrefaction. The learned Mr. *Borreel* lately assured me, he had eat bisket in *Holland*, which, being carried from *Amsterdam* to the *East-Indies*, was thence return'd good, by keeping it all the time in casks well-calk'd and lined with tin. A friend of mine has also a way of preserving fruit, for many months, by a bare artificial exclusion of the air. But it seems more difficult and useful to preserve flesh sweet in long voyages, without salt, which is apt to occasion the scurvy and other diseases. The means whereby the sailors do this, is, first to dress the meat, then cut it into slices; and laying them regularly one upon another in a close cask, they pour clarified butter thereon to fill up all the interstices; observing to keep the cask close cover'd. And I am not without hopes, that a method will be found to continue even raw flesh sweet, by something less corrosive than common salt. For not to insist upon the curing of neats tongues with salt-peter; I have, for experiment sake, kept a whole large puppy, for many weeks, untainted, in the midst of summer, by bare immersion, in a well-stopt vessel of spirit of wine; and might, but for want of opportunity,

tunity, have preserv'd it much longer And I question not but water will abolish the tast that the spirit communicates to what it thus preserves.

Sugar is a thing but lately known in these western regions: if we, therefore, consider how many bodies the confectioners and others, not only preserve by its means, but render grateful to the tast, it will seem probable that expedients, yet unthought of, may hereafter be found for the same purpose. Many concretes besides the sugar-cane may, perhaps, be brought to yield a sugar according to their respective natures: the *Indian* liquor, *Sura*, made from the juice of the cocoa-tree, by being evaporated and expos'd to the sun, congeals into a sugar, which tho', by reason of its brown colour, it be not much esteem'd, yet a skilful naturalist might possibly improve it. *Garcillassus* also, treating of the fruit of a *Peruvian* tree called *Melle* or *Mulli*, tells us, "that by rubbing it gently between their hands in warm water, they deprive it of all its sweetness; after which they strain the liquor, and leaving it a few days, to subside, it becomes a very transparent drink:" He adds, "the same, by boiling, becomes an excellent kind of honey." And that there is a great affinity between such vegetable honeys and sugar, appears from this passage of the diligent describer of the *Brazilian* plants, concerning the *Caraguata*, or *Erva Babosa*. "From an incision made in its shoots there flows an immense quantity of liquor, whereof they make wine, vinegar, honey and sugar; for the juice, being naturally sweet, is render'd much more so by boiling, as well as thicker; so that, at last, it congeals to sugar." Moreover, the governor of a colony in *North-America* assures me, there is in *New-England*, a kind of tree, exactly like our walnut-tree, the juice whereof, that distils from incisions, being gently exhaled, the remainder will congeal into a saccharine substance. The like was confirm'd to me by the agent of the colony of the *Masachusetts*. And, lastly, an eminent planter in *America* told me, that "the stalks of maiz afford a sweet juice, which, boiled to a syrup, gave a flavour to tarts and other things, not distinguishable from sugar." He added, that "both himself and others had in *New-England* made such a syrup with the juice of water-melons."

Besides the means already mention'd, we may hope to find out others to preserve the health of men. The ingenious attempts of *Sanctorius* may furnish us with new ways of discovering the wholesomeness or unwholesomeness of aliments. By the different weight of human bodies, upon using particular food, he observed, that pork, melons, &c. obstructed insensible perspiration, and were, by consequence, unwholesome. Tho', methinks, such observations shou'd be carefully made and repeated various ways in different ages, sexes and constitutions, before they are establish'd into aphorisms. And this procedure might enable us to prevent many distempers. Thus that aphorism of *Sanctorius*, "to eat and drink more than usual, once or twice a month, increases not the sensible evacuations, but renders a man lighter in the scale"; affords this important corollary, "A regular diet has not the advantage over a debauch committed once or twice a month; because the quantity taken in, excites perspiration to so surprizing a degree." And truly, experience teaches, that the promoting and suppressing of insensible perspiration, whereby the body may, in a day, discharge four or five pounds of excrementitious matter, has a greater share in continuing health and causing diseases.

To discover the wholesomeness or unwholesomeness of aliments.

The Usefulness of Philosophy.

diseases than is usually imagin'd: so that statics, an art long thought usefess to physick, may give us many useful directions relating to the preservation of health.

Philosophy helps to judge of the air, and water, as to their wholesomeness and unwholesomeness.

The naturalist can also devise means whereby to judge of the several kinds of aliment; and likewise of the temperature of the air of any place. Physicians generally suppose the light and pure water to be most wholesom; so that an easy contrivance to know when water has these properties wou'd be of service. We have been told, that water brought out of *Africa* into *England* was found, by common scales, to be specifically lighter than ours, by four ounces in the pint. And as this kind of difference is easily found hydrostatically, chymical experiments might be made to discover the respective qualities of different waters. Thus, many kinds of pump-water will not bear soap, and some will not dye scarlet or other particular colours. And I have often found an unsuspected sea-salt in water, by pouring thereinto a solution of fine silver, made in *Aqua fortis*: for as common salt, or its spirit, will precipitate the metal in form of a white calx, in such a solution; I imagined, if the water had, in its passage through the earth, gained ever so few saline corpuscles, they wou'd act, tho' faintly, upon the dissolved particles of silver; and accordingly upon their mixture, a kind of whiteness immediately ensued. This experiment has taught me to avoid such water, and to use in its stead, rain-water, or that which had been freed from its salt by gentle distillation.

Lastly, natural philosophy enables us to judge of the air, which is of the greatest consequence to the continuance of health; and to make farther discoveries therein, as to its wholesomeness or unwholesomeness in any place. And this *Sanctorius* teaches us how to estimate, from the weight of the bodies of the inhabitants. The late invention, also, of weather-glasses, manifests some of its properties. I shall only add here, that the various operations of different kinds of air upon certain sorts of flesh thereto exposed; upon some fading colours; upon bodies apt to tarnish or gather rust, &c. are more considerable than men seem hitherto aware of.

S E C T. V.

The usefulness of natural philosophy to the therapeutic part of physick.

WE come now, in the last place, to consider the therapeutic part of physick; whose improvement is, of all others, the most beneficial to mankind. I cannot, therefore, but wish that many physicians took more pains, than they do, to advance it. The design of physick is to relieve and cure the patient; and every part of the art is perverted, that does not conspire to promote this end.

The neglect of physicians to improve their art.

"A witty physician being lately asked, by one of the faculty, why, since his patient grew worse under languid remedies, he did not prescribe him something more generous; adding, that otherwise he must necessarily die; the other briskly reply'd, let him die if he will, so he die but *secundum artem*." I hope there are few of this man's temper! 'Tis pity there shou'd be so many learned men who think a physician has done his duty, when, after a discourse of the seat and nature of a disease, he foretells the event, and methodically applies a parcel of such languid medicines, that he knows are as unable to cure as to kill the patient. Such a dull

a dull procedure as this, whereto some lazy or conceited practitioners confine themselves, under pretence of its being safe, has exposed the whole profession to the cavils of empirics. The Lord *Verulam* tells us of one who used to say, "your *European* physicians are learned men, 'tis true, but they know nothing of "particular cures for distempers; so that he compared 'em to bishops, who have "indeed, says he, the power of binding and loosing, but no more." And Monsieur *Balsac* tells us of a physician at *Milan*, who boasted he had kill'd a man by the fairest method in the world. Such kind of stories are readily embraced, and turn'd to the disadvantage of the profession, by the greatest part of mankind; who send for physicians, not so much to have their distempers methodically told them, as to be empirically cured of them. And truly, he who struggles long with difficult cases, has a much greater share of my esteem than he who would raise a reputation on the success of his prognostics: it lessens my value even for the great *Hippocrates*, that his talent lay chiefly this way. Who had not much rather have his friend's life preserv'd by powerful remedies, than be told, for certain, the time he shall lose it; or be shewn in the open'd corpse, the cause of his death? But I am to shew that this curative part of physic is improveable by natural philosophy, and particularly by chymistry.

As goodness is to be regarded before pleasantness in a remedy, I shall not recommend the chymical preparations from their suitableness to take; yet physicians, methinks, shou'd be careful not to occasion their patients more uneasiness by nauseous medicines than is felt from the distemper; but cure them according to the old rule, *cito, tuto & jucunde*. The loathsomeness of some physic will, moreover, cause it to be rejected before it can perform its intended operation; for which reason, I presume, some physicians now use rosin of jalap rather than common purges. But chymistry may be farther useful to the practice of physic, by rendering evacuating medicines not only less nauseous to the taste, but less painful in the operation. Thus, mineral waters will work briskly, without occasioning such sickness and disorder as are frequent upon taking the common pills or potions: and a preparation I make with silver, will, taken in a very small quantity, pleasantly evacuate ferous humours; nor need the person be confin'd to his room who takes it. And medicines, will, I hope, be found to relieve patients without those chirurgical operations of burning, cutting and trepanning. *Helmont* says, "he knew a country fellow who cured all fresh wounds by a drink prepared "of burnt *Tilia*:" And I have more than once observ'd, that a scrophulous case was cured by *Paronychia*. If we may credit *Helmont* and *Paracelsus*, their *Præcipitatus diaphoreticus*, taken inwardly, cures cancers and the most inveterate ulcers: and if there be any truth in the relations of eye-witnesses, physicians and others, as to the effects of the weapon-salve and sympathetic powder, nature performs many such cures with less pain than the surgeon. I knew, as I have before said, a very ingenious man, possess'd, of a powder wherewith he constantly undertook to cure the cancer'd breasts of women, without any considerable pain; which I the rather believe it may do, because it seems to me a dulcification of arsenic, fixt with nitre, and carefully freed from its corrosiveness, by repeated distillations with fresh spirit of wine. *Bartholin*, mentions the cures of some hurts in the head perform'd without trepanning, where that operation was judg'd necessary. And that

The usefulness of
chymistry to the
curative part of
physic.

The Usefulness of Philosophy.

formidable way of stopping a hemorrhage from large vessels by the actual cautery, would be needless, did we know such remedies, as *Petrus de Osma* mentions, in his letter to *Monardes*, dated from *Peru*. “ In the city of *St. James*, “ says he, lying in the province of *Chyle*, *Anno Dom.* 1558, there were some “ *Indian* captives who cut off their own calves of their legs, which, for want “ of other provision, they broild and eat; but the greater wonder is, that by “ applying the leaves of a certain plant to the wounds, the flux of blood was “ immediately stopp’d”. I knew a rich man who had an uncommon fistula in his breast; and having, in vain, consulted the ablest chirurgeons of several countries, ’twas, at length, resolv’d to trace it with the knife: whilst they were preparing for the operation, a chirurgeon accidentally came in, and told the patient he could easily cure him without cutting; which he soon did, by the use of an almost indolent remedy; as the patient himself assur’d me; who, moreover, shew’d me his breast, and procured me some of the medicine. I shall here add, that a certain person having lately receiv’d a kick from a horse; the physician and chirurgeon employ’d, concluded the part gangren’d, and the patient in so desperate a state, that they desired to be excus’d attending him: upon this, a large dose of Sir *Walter Rawleigh*’s cordial was sent him; he took it; his fever and delirium left him; and, to the surprize of every body, his limb was perfectly restored. As a confirmation of these relations, I shall produce what *Piso* saw perform’d by the illiterate *Indians*. “ Such gun-shot wounds, says “ he, as, I remember, the *European* chirurgeons, both *Portuguese* and *Dutch*, thought “ incurable without amputation, were excellently cured by the natives, with “ fresh collected gums and balsams; and I can farther testify, that by nothing “ but tobacco-juice they cured ulcers and mortifications, which were given o- “ ver in the hospitals”.

Nor is rendering a cure agreeable, the greatest advantage the art of healing may receive from chymistry; it may, likewise, assist to discover the qualities, both of simple and compound medicines. By its means we learn the predominant minerals in medicinal waters; tho’ this is a subject that remains to be improv’d upon. And many trials have convinced me, ’tis rather our own, than the fault of nature, or of chymistry, that we remain so ignorant of medicaments: for tho’ the abstruse properties of specifics are not, I fear, easily learnt, without particular experiments and observations; yet many simples have unregarded qualities, such as soweriness, saltiness, corrosiveness, &c. residing in matter near of kin to salt, or sulphur; whereby they frequently operate. And these qualities seem to be discoverable by chymistry, without making trial on the human body. There are some plants whose juices will coagulate into a salt, which may be call’d essential; and such vegetables as these may be distinguish’d from others. And possibly, also, salts may differ in figure, taste, &c. so far as to be distinguishable into different kinds. If, likewise, we compare the salts of these vegetables with those of others, supposed to abound in volatile and saline parts; and, farther, examine other plants by chymical operations, whilst we remark their disposition to yield spirits or oils by fermentation, with other particulars, wherein they agree, or disagree, with each other, ’tis very probable we should make many

many discoveries of their respective natures and properties.* The infusion, or decoction, of some plants will become red by the addition of alkaline salts, whilst acids will much impair, or destroy, that colour. A little *Aqua fortis* immediately turns the red tincture of brazil, made with water, into a pale yellow; a small quantity of the lixivium of pot-ashes, dropp'd into an infusion of red rose-leaves, changes it into a muddy colour; and a little spirit of salt, into a fine red. A very strong solution of pot-ashes will precipitate a part of the decoction of red roses; and upon filtering the mixture, the grosser parts will remain behind, like mud, of a dirty colour; but the liquor transmitted, appears high colour'd like muscadine. As galls, a stiptic vegetable, afford a decoction, which, with copperas, makes the common ink; so other astringent plants may serve for the same purpose: for vitriol put to a decoction of oak-bark, or red roses, log-wood, or sumach, will make a writing ink; but that all astringent vegetables will do the same, I cannot affirm. Observing that a solution of vitriol, and the decoctions just mention'd, precipitated each other, I dissolv'd crystals of silver in water, which make a colourless liquor; and found they precipitated differently colour'd substances in the infusions of several vegetables, according to the several dispositions thereof. Thus, also, *Saccharum Saturni*, whilst dissolv'd in the spirit of vinegar, that extracts it, being put to an infusion of log-wood, *Lignum Nephriticum*, or red roses, they will precipitate each other. Add to these, that sulphureous oils, as *Oleum Tartari per deliquium*, dropp'd into the express'd juice of several vegetables, turns it, in a moment, to a lovely green, whatever be the colour of the vegetable. And tho' it be controverted whether quick-lime hath any salt that will dissolve in water, or of what nature it is; some experiments therewith have shewn me, that the water thereof, well made, will precipitate a solution of sublimate, and turn syrup of violets green.

I next observe, that also the medicinal qualities of animal substances are discoverable by chymistry; as we formerly shew'd by distilling the *calculus humanus*, how it differ'd from the stones of the earth. By distilling one parcel of crabs eyes, infusing another in vinegar, and a third in white wine, perhaps something peculiar to the nature of this concrete may be found. Nay, in some animal substances, the proper experiments will shew remarkable changes and properties, which are scarce perceptible to the eye. Thus I have remark'd in urine, kept close for many weeks, in a moderate heat, the virtues, depending upon its volatile salt, will be so heighten'd, that whereas spirit of salt being added to fresh urine, they quietly mix; dropping the same spirit into digested urine, an hissing and ebullition will presently ensue, and the volatile and acid salts soon after coagulate together into a third substance, a-kin to sal-armoniac. And so, tho' syrup of violets, dissolv'd in a little fresh urine, seems only thereby diluted; a few drops of fermented urine, presently change it to a deep green. Lastly, the same digested urine dropp'd into a solution of sublimate, immediately turns it white, by precipitating the mercury dissolv'd therein.

* Here is an unexceptionable method chalk'd out for establishing a *materia medica* upon a just foundation.

To discover whether bezoar be genuine or adulterate.

The following experiment may afford a certain way to discover whether bezoar be genuine or adulterate. We took 40 or 50 grains of choice oriental bezoar, reduced to powder, and, in a bolt head, poured on it six drams of good spirit of nitre, to try whether this liquor would prove a fit menstruum for it, as we found it did for the *Calculus humanus*. And tho' this effusion being purposely made in the cold, the liquor did not, at first, seem to work on the stone; yet, soon after, it fell violently upon it, and dissolv'd the greater part of it, not without noise, and a great effervescence. The solution was almost red, and the glass being set in a digestive furnace, the whole powder not only dissolv'd, but being left, for a night or two, in a north window, it afforded several saline concretions, much larger than could well have been expected from so small a quantity of matter; and these crystals, whilst they were yet in the glass, very nearly resembled crystals of salt-petre.

The chymical analysis of seed-pearls.

Two ounces of oriental seed-pearl, being put, whole, into a retort, and distill'd in a sand-furnace by degrees of fire, giving a strong one at the last; we obtain'd a little black oil, swimming upon the spirit, which was also dark and muddy, as if incorporated with some more oil. The weight of both these liquors was 23 grains, besides which, there stuck, to almost all the upper part of the retort, a thin film of oil, which, together with a streak of the like, reaching to the bottom of the receiver, we estimated at 3 grains more, and so reckon'd 26 grains for the weight of the whole ascended matter. The *Caput mortuum* amounted to full the remaining weight of the two ounces. The empyreumatical liquors, that came over, smell'd much like those of harts-horn; and the spirit was found to belong to the tribe of the urinous ones, or of volatile alkalies; for it readily hiss'd, and produced bubbles, with good spirit of salt, turn'd syrup of violets green, and being dropp'd into a solution of sublimate, chang'd it white; the oil that stuck to the retort, and which was fetid, like that of harts-horn, easily dissolv'd in rectified spirit of wine, and afforded a reddish brown solution. The *Caput mortuum* appear'd very black, and some grains of it were found readily dissoluble in spirit of vinegar: being calcin'd in a well cover'd crucible, with a strong fire, it became purely white, and weigh'd less, by some grains, than an ounce: and we also found, that being pulveriz'd, it tasted hot and bitterish upon the tongue, like good quick-lime, and that it was not only of an alkalifate, but a lixivial nature: for it presently turn'd syrup of violets green, and quickly afforded an orange colour'd precipitate, with a solution of sublimate.

Mineral earths to be inquired after.

But farther, the naturalist may, by this kind of procedure, increase the *matéria medica*; for chymical preparations will discover, that various bodies, not hitherto introduced into medicine, may be safely used; and that others, whose exhibition is attended with danger, may be more freely employ'd. Some chymists have lately made very good medicines out of zink, or spelter. It has often excited my wonder, to find physicians and chymists so negligent in discovering the qualities of mineral earths, and the like bodies that abound in most countries: for tho' they be look'd upon as stain'd elementary earth; I have, sometimes, seen a great variety of them dug up in a small spot of ground, so very different from each other in colour, taste, consistence, and other qualities, as

to make it very probable their natures were different. The true bole-armeniæ, and Lemnian earth, have been highly esteem'd, both by ancient and modern physicians, as antidotes for malignant diseases, and the plague itself; but as there are strong suspicions that these earths come to us adulterated, 'tis strange physicians should not try whether their own country cannot furnish them with as good. The attempts lately made, might, one would think, encourage them herein. For, without crediting *Johannes Montanus*, the supposed inventor of the *Terra sigillata Strigoniensis*, who affirms it to be transmuted gold; I find learned physicians prefer it to the Lemnian earth that's brought from *Turkey*; particularly, *Sennertus* highly recommends it against the plague, pestilential fevers, the bites of venomous creatures, the diarrhea and dysentery; he adds, that the chymists call it *Axungia solis*; which brings to my mind, that a gentleman once brought me a particular earth, found either in this, or some adjacent country, which, tho' it seem'd but a mineral one, afforded a considerable quantity of gold. They have, also, found in *Hungary*, an earth call'd *Bolus Tockaviensis*, said by *Crato*, to melt in the mouth like butter; and, in other respects, to be like bole-armeniæ; to which he preferr'd it against catarrhs, and found its success very great in the plague, that reign'd, in his time, at *Vienna*. And a very learned and successful physician of *England*, did lately, in pestilential fevers, prescribe, with a good effect, a red earth he found near the town where the plague then raged. That experienced chymist also, *Johannes Agricola*, greatly commends the *Terra Silesiaca* in several diseases, and equals it to the best of *Turkey*; telling us, moreover, what seems strange, that the spirit of it dissolves gold, as well as *Aqua regia*, tho' more slowly, into a red solution, which, in few days, precipitates the gold in fine powder. The same author relates, that he has seen another earth, found near *Westervaldt*, in colour between white and yellow, preferable to the *Silesian*, as yielding more salt than that; and dissolving silver so much better than other menstrua, as to render it potable, and parable into an useful medicine in cephalic cases. Nor am I surprized at the efficacy of these earths, considering how they may be imbued with mineral fumes, or tinged with mineral juices, which, having never felt the fire, retain all their loose and volatile parts, with a greater disposition to communicate their virtues, than when reduced to a more fixed state, or after the violence of the fire has thrown off their finer particles.

Such mineral bodies as are, of themselves, noxious, or unfit for medicinal uses, may, by chymistry, be reduced to wholesom medicaments, and so again enlarge the *materia medica*. Thus I knew arsenic brought, by salt-petre and spirit of wine, into a balsam, which, surprizingly cured a physician of my acquaintance, of dangerous venereal ulcers. And tho' bismuth has not, 'till of late, been used but as a cosmetic; yet *Cloßeus*, by calcination, and the addition of spirit of vinegar and *Cremor tartari* makes two medicines thereof, which he highly extols in the dropsy. A chymist also, of my acquaintance, prepares it, with common sublimate, into a white powder; a few grains whereof purge gently. Digestion, with powerful menstrua, &c. may reduce the rankest poisons to excellent remedies. And medicines, thus prepared, are highly extoll'd by *Helmont*. But tho' he speaks in an hyperbolical manner concerning them,

Chymistry may convert noxious medicaments into such as shall be wholesom.

The Usefulness of Philosophy.

yet, when I consider what great things are frequently performed by antimony, mercury, opium, even in the common preparations of them, it seems probable, that a more skilful management might thence obtain very extraordinary remedies. 'Tis said, indeed, that when a poison is corrected, it thereby loses its activity; but the simples abovemention'd, sufficiently shew this not to be true, which are, by that means, prepared into safe and effectual medicines. Thus the bezoar mineral, wherein, when duly managed, the purgative and emetic quality of the antimony is changed into a resolving diaphoretic and deobstruent one, becomes a good medicine; and is well recommended by *Riverius*. Crude *Asarum*, in like manner, known to be emetic, is very easily render'd diuretic, as some physicians aver, and serviceable in slow fevers. And that all other animal and vegetable poisons may be corrected, without losing their efficacy, is affirm'd by *Helmont* *. Crabs-eyes, resolved into their original milky state, he says, will do it in many vegetables; which was confirm'd from the experience of a physician of my acquaintance. Another, tho' no friend to *Helmont*, assured me, he had seen vegetable poisons, and, particularly, *Napellus*, so corrected by the volatile salt of tartar, as to become innocent. I shall say nothing here of *Helmont's Sal circulatum*; but as to the volatilization of salt of tartar, my own experience persuades me 'tis possible. 'Tis true, it must be a powerful corrector that can thus alter many different poisons; yet I cannot see but several particular bodies may, by a difference in the management, be prepared for medicinal use, without laborious or general correctives. Even lucky hits will, sometimes, afford us these discoveries; as *Helmont* found that *Asarum* loses its emetic property, and becomes a diuretic, by boiling in common water; tho' boiling it with the same degree of heat in wine, will not abolish its native quality. I have known white hellebor, opium, &c. when duly prepared, given, with happy success, in such quantities as would, otherwise, have proved pernicious. The violent emetic and cathartic properties of antimony, are daily destroy'd by calcination with salt-petre; corrosive sublimate, by repeated sublimation with fresh mercury, becomes a medicine that children may take with safety; and, even, that violent emetic, flowers of antimony, whose force the highest cordials are unable to abate, may, by bare heat and skill, be corrected, so that treble the common dose shall only prove a gentle diaphoretic.†

*Philosophy will
lessen the expence
of a cure.*

Natural philosophy brings another advantage to physic, by lessening the expence of a cure. The end of medicine, 'tis true, regards mens health, and not their purses; yet, a physician, in equity, should consider the poor. To say

* To shew an easy way of converting poisons into safe medicines, and, afterwards, how to apply these medicines as alteratives, occasionally, would be greatly to serve mankind, and advance the art of medicine. Whoever has the secret of applying the strongest medicines in due quantities, without promoting any sensible evacuation, and continues their use for the proper time, will, in chronical cases, cure such patients, as others would be apt to judge incurable.

ble. One way of converting poisons into safe remedies, is, to give them in very small doses, whereby their specific virtue, as *Dr. Mead* observes, may be discover'd. *Essays of poisons*, p. 132.

† *M. Homberg* knew a physician at *Rome*, who, even from real gall, prepared an excellent *Febrifuge*, which was so gentle as not to prove emetic. *Hist. de l'Acad. A. 1703. p. 64.*

nothing

nothing of the extravagant fees given to the physicians of some places; the *Apothecaries* bills, in particular cases, are so enormous, that after a recovery, the poor patients are often distress'd to pay them. Hence it happens, that the necessitous either languish without relief, or too late implore the help of a physician; whereas it were easy to prescribe cheap medicines, that should, at the same time, be efficacious. One way of doing this, is to avoid crowding a prescription with ingredients; tho' I am not for exploding all compound medicines: for complicated cases will, sometimes, require several qualities in one remedy, which are not, perhaps, obtainable from any simple. And altho' the chief ingredient in a composition often demands correctives, a vehicle, &c. yet I am of opinion, 'twould be no detriment, were physicians more sparing in bestowing them. The addition of needless ingredients increases the bulk of a medicine, renders it more difficult to take, nauseates the stomach, and prevents the efficacy of the more serviceable parts therein. 'Tis, moreover, a great impediment to the discovery of the virtues of simples, thus to huddle and confound them together; for when a number of ingredients are mix'd, 'tis impossible to know the operation of each. Again, tho' from exhibiting one of these complex medicines, a physician only expects an effect suitable to the single quality predominant in the whole; several of the ingredients may have such particular effects, as he never dream'd of; and excite the latent seeds of other distempers. Thus, I remember, an oculist told me, he had frequently found that parsley, accidentally used, either internally or externally, would cause great pain, or inflammation, in sore eyes; and my own were thus affected once by eating sauce, wherein this herb was an ingredient. 'Tis said, in favour of these compositions, that tho' some noxious ingredients enter them, they are so qualified by the rest, as to become innocent: yet in venice-treacle, the small quantity of opium, tho' mix'd with above sixty other drugs, retains its virtue. And, perhaps, the reason why those, who are continually taking physic, are usually troubled with one distemper or other, is because, by the variety of the medicines they use, such humours are disturbed, as might, otherwise, have lain dormant. But another argument for the use of compound medicines is, that how numerous soever the ingredients may be, they so temper and allay each other, that the result of the whole, is one chief medicinal quality. And, in some cases, this seems probable enough; for a decoction of galls, and a solution of copperas, neither of which a-part are black, make ink by their mixture; as brimstone, salt-petre, and charcoal, join'd in due proportions, compose gun-powder. Yet, tho' a new property arises, when a multitude of ingredients are added together, 'twill, I fear, be very difficult to determine beforehand what it will prove, whether noxious or harmless; or whether the principal parts shall be improv'd, or impair'd. Thus, tho' crude mercury, crude nitre, and crude salt, singly administred, even in large quantities, are innocent; yet a composition of the three makes a sublimate, a few grains whereof will poison a man. Tho' I cannot, therefore, commend the use of those famed compositions, mithridate, venice-treacle, and the like, when two or three simples might do as well; yet, because long experience has shewn them to be good medicines in many cases, they ought not to be neglected. But 'tis one thing to use such a composition, after tryal has

Compound medicines consider'd.

proved.

The Usefulness of Philosophy.

proved it a lucky one, and another to rely on a huddle of ingredients, before experience has manifested the nature thereof. In a word, tho' I had no great opinion of the contrivers of the medicines, into which ingredients are thrown by scores, I would not reject an effectual one, tho' it proved so by accident, rather than design. A wise man may use a remedy, that none but a fool would have devised.

Another way to lessen the charges of a cure, is to throw out of compositions such ingredients as are unfit for the management directed. 'Tis not without surprize and indignation, that I see in the prescriptions of physicians, and, even, in their public dispensatories, such a want of skill in this particular. 'Tis usual with them to order many things to be distill'd *in Balneo*, which, with that heat, will yield nothing, or only a little nauseous phlegm; while the virtues of the ingredients, remaining behind, are often thrown away after the distillation is over. 'Tis, in most cases, very unsafe to conclude the virtues of distill'd liquors the same, as of the ingredients they are made from.

Again, such ingredients, as used separately, would be effectual, are often spoil'd by an unskilful mixture. I have seen many processes, wherein saline substances of contrary natures are order'd; tho' there are scarce any bodies in the world more opposite to each other than acid salts, whether volatile, or fixed. Hence it frequently happens, that two good ingredients are destroy'd. And this is the case, when acid juices are order'd to be distill'd with alkaline salts; thus spirit of urine, and spirit of salt, distill'd together *in Balneo*, yield nothing but phlegm; leaving their active parts behind, coagulated into a fixed substance, a-kin to sal-armoniac. In like manner, where active salts are made ingredients, unless judgment be employ'd in the composition, they frequently destroy each other's virtue, and degenerate into a new thing; and thence, perhaps, out of many useful ingredients, one bad medicine arises.

Many materials
used in physick,
have little virtue,
and others neg-
lected, that have
more.

The naturalist may farther contract the cost of medicines, by shewing, that many materials, used in physick, have little, or no medicinal virtue, at least, not equal to the price they bear. I am not altogether for rejecting leaf-gold, and precious stones; the dissolvent in the stomach, may, thence, possibly, extract some useful parts, and, thereby, render them serviceable to such as will go to the price of them. I have, with different liquids, easily, and without heat, obtain'd tinctures from gems, and sometimes dissolv'd them: nor do I despise them exhibited in substance. Glas of antimony, which appears like a ruby, will readily impart an emetic quality to fluids; tho' as well rubies, as other gems, differ therefrom in fixedness. Gems will endure a violent fire, and the force of strong corrosive liquors; but the glas of antimony yields to spirit of vinegar, and a strong fire dissipates it into fume. However, 'tis one thing to shew it possible for the human stomach to act upon gems and gold; and a different one to prove that it really does so, and, by that means, gets out the specific virtues ascribed to them. And were even this demonstrated, it remains to be confirm'd, that these do more than cheaper simples: so that I suppose, physicians might do well to prescribe the latter, whose virtue is unquestionable, to the poor, instead of the former, whose dearness is certain.

What

What wonderful powers may reside in the true *Aurum potable*, I shall not now Aurum potable prepared. particularly inquire: the attempts, however, to make it so seldom succeed aright, that many have pronounced its preparation unfeasible. But were it not; why must it possess such virtues as others boast of? The current reports concerning it, arise, not from experiments, but in great measure the authority of books that bear fictitious names. And some, I fear, commend it, from a supposition that the gold is hereby render'd volatile, or exalted to a spiritual nature; and argue its excellence from the nobleness of the metal. But, for my part, tho' I have a menstruum that will soon, with a gentle heat, bring over crude gold enough, upon a first or second distillation, to afford a high yellow volatile tincture; yet as I can quickly recover a malleable gold therefrom, I dare not pretend to do wonders with the metal dissolved therein. But to make an *Aurum potable* in an hour or two's time without a furnace, or any other distilled liquor than rectified spirit of wine, I have several times prepared a saline mixture, consisting of one part of sal-armoniack, two parts of roch-alum, and four of pure nitre. This, being well pulverized and mixed, I rubb'd diligently in a marble mortar with 15 or 16 parts, in weight, of the whole mixture, of leaves of gold; and placing the whole in a small new crucible, with a few kindled coals around, at a small distance from it, to neal the vessel, I soon after set them nearer, till the heat made the matter melt; and with that gentle fire I kept it in fusion till it visibly emitted no more fumes, but grew dry again. Then presently taking it from the fire, whilst it was yet warm, I dug it out as clean as possible, and having seasonably pulverized it, that it might not attract the moisture of the air, I put it to some highly ratified spirit of wine, which within an hour or less was thereby enobled with a rich golden colour. And this I found by various tryals, purposely made, to be a real solution of gold. And farther, to make a preparation, wherein gold is reduc'd to very minute parts, without the help of mercury, or of any precipitation by means of sharp salts, we took refin'd gold, and dissolv'd it in clean spirituous *Aqua regia*; and instead of precipitating the clear solution with oil of tartar *per deliquium*, spirit of sal-armoniack, &c. we first, with a very moderate heat, drew off the superfluous liquor, whereby the gold, with the remaining part of the menstruum, was left in the appearance of a thick oily liquor. This done, we pour'd upon it a treble weight of vinous spirit, totally inflammable; and in a short time we had a very subtil powder, or high-colour'd calx of gold, that subsided at the bottom; the menstruum being strangely dulcify'd as to tast, and become fragrant in point of smell. A very few days after, we decanted the liquor, and put on it fresh ardent spirit; when leaving them a while together, there subsided the like well-colour'd calx, more plentifully than before; whilst the menstruum acquir'd such qualities as made it seem likely to prove an useful medicine.

This powder of gold, tho' it seem'd not to require it, we farther purified for internal use, by burning a totally ardent vinous spirit, twice or thrice thereon, to carry off with it any little corrosive or saline particles, that might have still adher'd to the metalline ones.

The spirituous *Aqua regia*, here mention'd, which may probably be a more innocent menstruum in preparing gold for medicinal uses, I very easily make, by mixing one part of good spirit of salt with two of strong spirit of nitre.

But

But should these, or the like preparations, possess medicinal virtues, they might, perhaps, be more owing to the menstruum than the metal; whose nobleness depends upon the estimation of men, and is, accordingly, in some countries less esteem'd than iron or copper. Nor, because it is a fixed and precious body, must it therefore be an extraordinary medicine; for then diamonds wou'd hardly be rank'd among poisons. Be this as it will, 'tis absurd that physicians should prize simples, like drugsters, according to their dearness, or for coming from remote regions; as if God had made provision only for the rich, or those who trade to the *Indies*. On the contrary, it frequently happens, as we before observ'd, that the *Caput mortuum* of the chymists, which is sometimes thrown away as useless, may have greater virtues than those reputed nobler parts, forced from the original bodies. And a despised common simple, nay an insect or an excrement, may in some cases prove nobler medicines than an extract, elixir, or a quintessence. Thus the supposed vile *Caput mortuum*, that remains after the distillation of *Aqua fortis*, dissolved in common water, yields a salt, which being only depurated by frequent solutions and filtrations, becomes the famous *Panacea duplicata*, or *Arcanum duplicatum*, purchased, at the price of 500 dollars, by that great chymical virtuoso the Duke of *Holstein*; concerning which that prince's physician thus writes to *Schroder*. "Our court has a thousand times experienced the virtue of this salt, in hypochondriacal cases, continued and intermitting fevers, the stone, scurvy, &c. the dose is from one scruple to two." And another physician, who frequented that court, assured me of the diuretic and deobstruent quality of this medicine. But what appears more surprizing, is, that the *Caput mortuum* of vitriol, when all the oil is drawn out, and it's fixt salt carefully separated by water, the mere seeming *Terra dammata*, that remains, is parable into a nobler medicine than, perhaps, either the oil, spirit or salt, of that mineral. That the bezoar-stone, sold at an immense price, is every way inferior in virtue to the *Calculus humanus*, we have the testimony of the experienc'd *Bontius*. And foot, tho' esteem'd a vile commodity, is an useful one in physic. *Riverius* commends it in pleurisies; and I have found that a spirit, made thereof, is no inconsiderable liquor. I know too that the medicines of some eminent physicians have the spirit of foot for their principal ingredient. I remember also an empiric of learning, who became very famous for curing difficult distempers of the brain, by a remedy he called his *Panacea*, or *Aurum potabile*, which, in exchange for another chymical secret, I learnt of him to be chiefly spirit of foot, wherein the flowers of sulphur were so dissolved, as to swim about in small drops of a golden colour.

The express'd juice of stone-horse dung will give relief in a suppression of urine, to those who are troubled with stitches or wind, and even in obstructions of the liver and spleen. This homely remedy has, to my knowledge, been so successfully used by a great lady, that she prefers it to chymical essences and elixirs. And many of the poor were cured of the plague with the same, used as a *succedaneum* to the powder of ripe ivy-berries, when that dreadful distemper lately rag'd in *Ireland*.

The medicinal virtues of human urine, both externally and internally used, require a volume to enumerate: and an industrious chymist has already made a collection towards it. An ancient gentlewoman, whom I knew, was advised

vifed, for a complication of obftinate chronical diftempers, to drink her own urine every morning; which reftored her almoft to a miracle. A perfon of great quality went thro' the fame courfe, after having found the *Spaw* ineffectual. And once I taught an empiric a cheap preparation of this excrement, which render'd him famous about the country, for the cure of many difeafes, efpecially the pleurify.

Large quantities of wholefom human blood are thrown away every fpring and fall, as ufelefs; yet by a fkilful management it will, without any thing befides fpirit of wine to keep it from corrupting, eafily afford a fpirit and volatile falt, preferable, I believe, to thofe of harts-horn; for they have cured confumptions, afthmas, &c. to the admiration of my felf and others. To give one inftance more, of the efficacy of things apparently defpicable; the common wood-lice or fows, which I have both taken my felf, and frequently recommended to others, are excellent, not only for the ftone in the bladder, but againft other diftempers. A flight preparation of them was discover'd, by a learned phyfician, to be the grand fecret of an empiric, famous in *England*, for giving relief in fits of the ftone; and I knew an ancient gentlewoman, skill'd in phyfic, who, having loft the fight of one eye by a cataract, had the fudden lofs of that of the other foretold her by the oculifts; but, to my furprize, ſhe continued to enjoy it in great perfection, by the help of millepedes infufed in white-wine; which were recommended to her by a woman who had herfelf, thereby, been cured of a recent fuffufion in both her eyes. An ingenious phyfician, alfo, affured me, that he met with a woman in *Holland* who was cured of a real cataract by the juice of the fame animals; being advifed to ufe it by an empiric, reported to have therewith performed feveral cures.

Surprizing things have, alfo, been done in fore and exulcerated breafts of women by taking millepedes, bruifed, in proper liquids; linen cloths being dipp'd in white-wine and applied warm to the part during the time of their ufe. Let me add, that I have feen a young lady who, by various fifulas in feveral parts of her body, was lamed, emaciated and weaken'd, to fuch a degree, that her life was defpair'd of; yet by the frequent ufe of a diet-drink, wherein millepedes were the chief ingredient, her ulcers fpeedily heal'd, and a good habit of body was reftored. And many other cures perform'd with the fame medicine, were afcribed to this fingle ingredient. Another young lady I knew afflicted with a radicated epilepsy; who, after numberlefs medicines, prefcrib'd by phyficians, had prov'd ineffectual; and after her fits came upon her feverely, eight or ten times a day, was cured by the powder of true miftletow of the oak, continued for fome days, near the full-moon, in the quantity that wou'd lie upon a fix-pence, every morning, in black-cherry-water, or beer. And tho' this remedy had fcarce any vifible effect upon her; yet, after the firft day it was taken, the fit never return'd but once. The perfon, who advifed this remedy, profefs'd he had therewith constantly cured that diftemper, when he cou'd procure the genuine fimple. *

* The ufe of this medicine is ftill continued with tolerable fuccefs; but many queftion, whether it be a fpecific for the epilepsy.

To save trouble and
charges in making
chymical prepara-
tions.

To know how to save trouble and charges in preparing chymical medicines, is another way to lessen the expence in the curative part of physic. It were wrong to suppress all chymical remedies because of their dearness; for altho' a large price be paid for a considerable quantity thereof, yet a dose may come cheap enough. There are also *Galenical* medicines sold as dear, the largeness of their dose consider'd, as the chymical; yet when the prices of the latter are exorbitant they shou'd be retrench'd. There are two things blameable in physicians as to this matter; first, their making use of chymical preparations, when simples or slight compositions wou'd serve as well; and, secondly, their bestowing too much labour in preparations. There are physicians so fond of furnace-productions, that to cure a cut finger, they'll apply some chymical oil or balsam; and, in slight distempers, have recourse to mineral remedies, or such as, occasioning great and unnecessary alterations in the body, frequently do harm. Yet *Paracelsus* often used simples for the cure even of formidable diseases. And tho' I am of opinion, that powerful or universal remedies are unobtainable without chymistry, and perhaps without minerals; yet I cannot but think, that simples, or cheap *Galenical* compositions, may cure most particular diseases; and afford more noble specifics than the chymists imagine. *Helmont* ingenuously confesses, "he believ'd simples, alone, sufficient to cure all distempers;" and scruples not to say, "there may sometimes be greater virtue in them, as they are afforded by nature, than as prepared by the fire." And, questionless, the specific properties of many simples are destroy'd in chymical preparations. The most judicious chymists acknowledge, that pearls barely reduc'd to fine powder, are a better medicine than the magistery they make of them, by solution in acid spirits, precipitation with oil of tartar, and a careful edulcoration. The same is very observable in the magistery of harts-horn; for whereas, this substance, when crude, makes a jelly with water; the magistery remains a fixt powder, insoluble even by acid menstrua; and scarce affords any smoke when thrown upon a hot iron. I never found the vulgar chymical essences, or elixirs, half so effectual in stopping hemorrhages, as equal parts of hen-bane seed, and white-poppy seed, beat into a stiff electuary, with twice their quantity of the conserve of red roses. With this remedy, given in the quantity of a nutmeg, or walnut, both my self, and others, have frequently cured profuse bleedings at the nose and elsewhere. Nor did I ever see such surprizing effects from the most elaborate chymical preparations, in spitting and vomiting of blood, as from a syrup made only of plantain juice, that of comfrey-roots, and fine sugar. And unusual cures of this kind have herewith been perform'd by two eminent physicians.

But I observed, that in cases where chymical medicines are proper, the preparation thereof is too tedious and expensive. A chymical process is seldom order'd or esteem'd, that requires not some weeks to complete it; as if the embryo wou'd otherwise prove abortive; or the medicine cou'd not cure with expedition, that was not slowly prepared. And this humour prevails, not only in making the standing medicines of the shops, but even extends to those design'd for extemporaneous uses; and, perhaps, for acute cases too. Now, were a physician to wait till these remedies were made upon such emergencies; his patients, I fear, wou'd, by that time, have little occasion for them. Besides, this tediousness in the pro-

cess

cess is often increased by the unskilfulness of the prescriber. 'Tis frequent, we see, in chymical writings, to submit the materials of the medicine to successive operations; yet, were you to demand a reason for each step taken herein, the operator might finish his process before he cou'd give you a satisfactory answer. Nay, these processes are sometimes so injudiciously lengthen'd out, that the operations thwart or destroy each other; and leave the medicine in a worse condition than 'twas found. And thus, as we just observ'd, the virtues in the common magisteries are lost. I lately met with a notable instance of this kind, in a famous modern chymist; who, to purify the fix'd salt of vegetables to its height; after numberless solutions, filtrations, and coagulations, orders it to be dissolved in *Aqua fortis*; whereupon, says he, it will become very pure and crystalline, and not easily dissolvable in the air. And truly, he is in the right; for, by adding *Aqua fortis* to some vegetable salts, and afterwards exhaling the superfluous moisture, I used to make good inflammable salt-petre. See with what judgment this solution was order'd, to depurate the salt the farther; and how fit such authors are to be credited, in attributing to such salts the improved virtues of the respective vegetables that yield them! In some cases, 'tis true, as in making active and powerful menstua, exact depurations are necessary; but in many other cases, such a subtilization of a remedy, which often renders a process incredibly tedious, is more insignificant than chymists imagine; and sometimes proves detrimental, by robbing it of those fine parts whereon its specific virtue depends.

Again, as a cure becomes more expensive, thro' the charge of the several chymical operations whereby medicines are made; a farther acquaintance with experimental philosophy, may suggest cheaper and better ways of performing them, than those now used. And I question not, but chymists may be instructed to make better furnaces for several purposes, than they are hitherto possess'd of; for the professed artists among them, having been generally ignorant in other parts of learning, and particularly in mechanics; their furnaces and utensils have never been contrived to the best advantage; with regard either to the husbanding of their fire or fuel, or the intending and remitting its heat. 'Tis an agreeable surprize, to see how many vessels may be duly heated by one small fire, when the furnace is so contrived, that the flame may pass thro' various windings to the vent. And as to the intenseness of heat, I have seen odd effects thereof, without the assistance of bellows, in a furnace capable of receiving but few coals; for I sometimes vitrify'd even crucibles herein; and thought, by a small alteration, I cou'd melt its sides down. But a credible person, disciple to *Cornelius Drebell*, cou'd do more than this. He assur'd me, he had a way of building furnaces, wherein he, by the single force of the fire, made *Venetian* talc flow; which I confess myself unable to do by the fire of a glass-house. Experience, however, has assured me, 'tis easy to make a furnace give heat enough, without the least help of bellows, to cupel both gold and silver. The heat in furnaces may also be better regulated than at present: and I look upon the skill of intending and remitting hereof at pleasure; and particularly, of continuing it long in an equable degree, as a thing of greater moment, both to physic and philosophy, than men seem appriz'd of. With lamp-furnaces, well order'd, many things may be per-

Philosophy may suggest cheaper and better ways, than the common, of preparing medicines.

form'd in imitation of nature; and several of my friends have, by means hereof, brought hen-eggs to manifest animation. That furnaces, also, may be so built, as to require but little attendance, appears from the obvious invention of athanors, or tower-furnaces; wherein the fire is, for many hours, supplied with a small quantity of coals, without ever burning much faster than is design'd: and that the labour of blowing may well be spared, and the annoyance of mineral fumes, in good measure, avoided, appears from those furnaces made with a pipe to draw the air, as in *Glauber's* fourth furnace, or otherwise. I might add, that casting the materials to be prepared upon live coals, as *Glauber* orders, in his first furnace, is sometimes a cheap and expeditious way of preparing particular minerals; tho' his method, of making spirit of salt in that furnace, fail'd both with me and some of my acquaintance. There are, also, several other more commodious contrivances of committing things to a naked fire; so that, upon the whole, I cannot but expect, many good expedients of employing fire to chymical uses, will hereafter be found; which are not, at present, so much as dreamt of.

Surprising things
perform'd: i. by chymistry.

And not only furnaces, but the vessels that immediately contain the materials to be prepared, are, doubtless, capable of improvement. Those earthen retorts, called *Glauber's* second furnaces, if made of good matter, may be render'd useful. The great convenience of sealing glasses hermetically, and of glass-stopples for bottles containing corrosive or subtile liquors, &c. persuade me, that, cou'd we prevail with the potters and glass-men to make their respective vessels according to direction, many things in chymistry might be made better and cheaper than they now are; and others perform'd, of which our present vessels will not admit. And as 'tis possible to render glass malleable, if that relation of *Pliny* and *Dion Cassius*, concerning an ingenious man who was put to death for it, be true; so, now chymistry is improved, cou'd this art be retriev'd, 'twou'd be very beneficial to mankind; by enabling us to make abundance of experiments which are now scarce practicable. Such an attempt must appear the more promising to chymists, because *Raymund Lully* expressly says, "it's one of the principal effects of the philosopher's stone to make glass malleable." * And an expert chymist, not credulous, and, in a word, very well worthy of credit, assur'd me, that he had himself seen at *Mentz*, in the hands of a gentleman of *Switzerland*, a piece of glass, about the bigness of a shilling, which was red and transparent, like glass of antimony made *per se*, and which the owner affirm'd he had hammer'd in the presence of the elector of *Heidelberg*. But the *Switz* gentleman perceiving the other indispos'd to believe so strange a thing; after he had confess'd the glass to have been given him by an excellent chymist in his country, permitted him to lay the piece upon an anvil, and to strike seven or eight strokes with a hammer upon it; by which means he found, that tho' it was not malleable like

* 'Tis pretended, that the expression, to make glass malleable, is a contradiction; since to be malleable, it must lose its transparency; that is, cease to be glass; for say some, how can its parts retain one certain order under the hammer; which alone fits it to transmit the rays of light?

But, perhaps, this favours more of quibble than of argument, to chymical philosophers; who consider, that glass in fusion, or in powder, is still glass: tho' even to these, I believe, the problem seems almost desperate.

neal'd silver, since it began to crack at the edges like silver that is over-hammer'd; yet it did really stretch under the hammer; growing more thin on the beaten part, and having visible marks or impressions made on it by the edge of the hammer. But as to my own opinion about such a preparation, and the uncommon inducements I have for it, I must be here excused. However, as strange things as this, seem to be performable.

Relating to a judicious person what a physician of *Bruxels* affirm'd to me, that he himself had prepared three or four resuscitable plants, one of which he presented to the marquis of *Castel Rodrigo*, governor of the *Spanish Netherlands*, where this gentleman had lately been; he told me, that, an apothecary of *Namur* really had prepar'd resuscitable plants in a different way from what others pretend to; and that he could prepare a great variety of them. And many of these, he assur'd me, he had seen preserved in distinct glass-bottles; tho' the apparitions that were exhibited, shew'd not the peculiar colour, only the shape of the plant; but this so well, that he could perfectly distinguish, and easily know, the several plants; instancing particularly in *Carduus benedictus*, and camomile.

And the difference betwixt this way of exhibiting plants, and that mention'd by *Quercetan*; pretended to, also, by others; I found by this gentleman's answers, to consist chiefly in these two things; the first, that the apothecary's plants did not, as the others, seem to grow up into the air included in a seal'd vial; but were seen growing in a clear liquor, wherewith the bottle, that contain'd it, was almost fill'd; and next, that tho' to make the apparition, mention'd by *Quercetan*, and others, the application of an actual heat is affirm'd to be requisite, upon the absence of which, the phantastical plant relapses into its ashes; in the formation of the apothecary's vegetables, he doth not employ any actual heat, but only the shaking of the bottle; for upon that agitation the prepar'd ashes or powder being rais'd from the bottom, and dispers'd quite through the liquor; when the glass is set by, in a quiet place, the scatter'd particles, by degrees, unite together so as to compose a model of the plant they once belong'd to. And heat not being requisite to their formation, these plants do not quickly, as the *Polonian* physician's phantastic vegetable, recorded by *Quercetan*, fall back into a powder; but if let alone, continue till the preparer thinks fit, by a gentle agitation of the bottle, to dissolve the loose texture *

An ingenious person, very worthy of credit, inform'd me, that he was employ'd, some years ago, by a *German* physician, to distil a certain known mineral, which he perform'd in a naked fire, with so good success, that he had from about half a pound of the mineral, near three drams of a liquor; which he included in a glass with a bubble, and a slender neck, like a weather-glass; but

* These occur, says *M. Homberg*, many productions in chymistry, that, in some sort, resemble the vegetation of plants; but when closely consider'd, they prove greatly different therefrom. These productions are divided, by this author, into those which consist of a pure massy metal, without any other mixture; those which consist of a metal dissolved in a menstruum, wherewith in remains mixed; and, lastly, those which contain nothing metalline; only simple, saline, terrestrial or oily substances. Of all these he gives several examples; with the processes to make them; and the solutions of the phenomena therein. See *Memoir. de l'Academ. A. 1710. p. 556-572.*

The Usefulness of Philosophy.

tho' the liquor, at first, reach'd not above the bubble, only fill'd it to the bottom of the pipe; yet as the moon increas'd, this liquor, as the doctor expected, by degrees expanded it self in the glass, so that about the full-moon, it reach'd an inch into the pipe, and upon the decrease of the moon, it subsided by degrees to the bottom of the pipe. And when I ask'd, whether the vessel were carefully stop't? he answer'd, that it was not only so, but hermetically seal'd, like one of my thermometers with spirit of wine; which he had seen. This the relator averr'd to me upon his own observation, and being desir'd, he readily gave me a description of the mineral, and a direction where to procure it; adding, that the same doctor made the like tryal with another mineral, a-kin to this; with which having heard that such a thing had been perform'd, gave me occasion to propose the question.

Upon asking an inquisitive traveller, who lately waited on a *German* prince, addicted to chymistry, and was employ'd by him in his private laboratory, some questions about the ore of bismuth or tin-glass, whereof there is said to be a mine in that prince's territories; and, in particular, whether he had observ'd any thing of the varying bulk of a strange liquor obtainable from it; he answer'd, that he had made many tryals upon this mineral, and that particularly by his prince's command, he had distill'd a considerable quantity of a certain sort of it; whereby he obtain'd a liquor, which being, by rectification, freed from its superfluous phlegm, amounted to about half a pint. This liquor was put into a vial, which it almost half fill'd. This vial being exactly stop'd, was set aside in a quiet place; where, (according to the prince's expectation) as the light of the moon increas'd, from the new-moon towards the full; this liquor gradually swell'd, very manifestly and considerably; so that when the moon was in the full, the liquor reached almost to the top of the glass; and during her wane, as the light decreas'd, so did the bulk of the liquor, which was always least at the new-moon. He also readily told me the way he us'd in making the distillation, which, he said, required an intense degree of fire.

An ingenious physician assur'd me, that at a place near *Amsterdam*, there liv'd a kind of a farmer, reputed very curious; who shew'd him, among other things, a considerable quantity of quick-silver wholly of the colour of gold; and that having purposely (with water) divided it into many globules, each of them retain'd the same rich colour. He farther told me, that the possessor of this yellow mercury, having put some of it over a fire in a convenient vessel, it quickly lost its fluidity, and was precipitated into a red powder.

Another very learned and experienc'd physician assur'd me, that an adept shew'd him a running mercury of a lovely green; which he purposely throw'd upon a carpet, and found the globules, whereinto 'twas by this means divided, to be of the same fine green that had beautify'd the whole mass. But to return.

Spirit of wine, which is one of the most chargeable things in chymistry, requires, in the ordinary way, much time, and many rectifications, to clear it of its phlegm; but I have seen a vessel, made of tin or pewter, invented by a surgeon, at *Paris*, that wou'd at one distillation, bring it over, from wine itself, pure and most highly rectified. Nor do I question, were the nature of fermentation

The Usefulness of Philosophy.

71

mentation better understood, but inflammable spirits might be obtain'd from vegetable substances much cheaper than wine: for not only cyder, perry, &c. but most grains, also, and berries, will yield it. In *Barbadoes*, they make their *Mobby*, a kind of wine, of potatoes: nay, such a liquor is, likewise, obtainable from some sorts of leaves; and I have found roses, well fermented, to afford a good inflammable spirit. And, as to the preparation of pure spirit of wine, I have a way that exceedingly lessens the time and trouble of rectifying it, tho' without any particular contrivance, either in the furnace, or glasses.

The naturalist, we hope, may, also, teach us good husbandry in heating our furnaces, either by discovering new combustible materials, or introducing some cheap alterations in those the several places afford; so as to augment, or render the heat more durable, and their scent less offensive; or else by directing us to ways of performing without fire, what we usually do by it's means. In some countries, as here in *England*, where charcoal, alone, was formerly burnt in furnaces; pit-coal supplies it's place. They who distil large quantities of *Aqua fortis*, do it with coals much cheaper than those of wood: and, I find, that the same fuel may be used in other kinds of furnaces, where the bars of the grate are set wider; if a little char-coal be mixed therewith to promote it's kindling.

And as pit-coal, of late, has been found among us, where it was before unknown, so, 'tis probable, other countries, were the proper searches made, may, also, afford the like. But the smoke of this coal being very offensive, and other inconveniencies attending it's use; a way has been found to char and reduce it into coherent masses, of a proper size. 'Tis true, it is sold almost as dear as charcoal; yet those who consume large quantities, find it near twice as cheap; because it lasts much longer, and gives a heat far more intense than the other. It would, therefore, be a very useful thing in chymistry, to be able to char-coals, without the use of those pots whereto their present price is owing. And that this were easy to do, I should directly shew, would it not prejudice the industrious chymist, whose invention it is. In *Holland*, likewise, they have a way of charring peat, a kind of turf, which might serve for fuel in chymical operations; tho' the manner of charring be not yet known in several countries, where, perhaps, peat might be found. Nor is it improbable, that some places might afford combustible materials, which have hitherto no name assign'd them by minerologers. I have seen a sort of coal, part whereof look'd like marcasites, that burnt clear, and with a good flame, to whitish ashes, without stopping the grate.

But, as we improve in natural philosophy, 'tis possible, ways may be found to excite heat, sufficient for many chymical processes, without the assistance of common fire, or fuel. Considerable heat is producible by the attrition of hard bodies, as iron and steel. And, perhaps, such an heat might, by a cheap contrivance, as of a water engine, be produced in iron vessels to digest with.

This I know, that from some succulent plants a liquor may be drawn by barely exposing them, in proper glasses, to the rays of the sun. The heat of
horfe-

The Usefulness of Philosophy.

horse-dung, which chymists use for digestion, might serve to distil some fermented liquors; at least, when augmented by a skilful addition of quick-lime and water. Many cheap materials, I doubt not, might, upon trial, be found to make portable digesting furnaces, without fire, clear of the inconveniencies attending the use of horse-dung. For, not to mention the spontaneous heat in malt, and other sorts of grain, and fermenting berries; I, many years ago, found, that by surrounding glasses with refuse hay, well pressed, and uniformly wetted, it would, for several days, afford such an heat, as render'd that of horse-dung needless: and yet the greatest quantity of hay, that I ever employ'd for this purpose, was too little to take fire of itself; as sometimes happens in stacks of it. And where actual fire is required, skill may lessen the occasions of it. To make spirit of fresh urine, near nine parts in ten are generally drawn off as phlegm, before the volatile part begins to rise; but a knowledge of the nature of putrefaction, will save this expence of fire: for, let the urine stand, well stopp'd, for eight or ten weeks, and the spirituous parts will so disengage themselves, that the gentlest heat will raise them first, and leave the phlegm behind. And, even, from fresh undigested urine, I can, with ease and cheapness, make a subtile spirit rise with a gentle heat, before the phlegm; only by pouring it upon quick-lime, just before distillation, 'till it rise a few fingers breadth above the upper surface thereof.

The volatile salt of urine may easily be obtain'd with an exceeding small degree of heat, barely by tempering the extract of urine with a convenient quantity of wood ashes; whereby the volatile part of the salt of urine is so freed from the grosser substance, that it will, with strange facility, ascend fine and white to the top of very tall glasses.

To rectify that grand menstruum, spirit of wine, you need only put about an inch thick of tartar, calcin'd white, and very dry, in the bottom of a tall, slender glass body, and pour thereon as much spirit of wine, once rectified, as will, when they have been shaken together, swim a finger's breadth above the tartar; and draw off the spirit with a gentle heat. This method saves the great expense, both of the time and charges, required in the common way of rectifying it; for, even, what rises last here will burn all away, yet leave only a mere phlegm behind, after distillation; and the same calx, well dry'd, will serve more than once in this operation. And, even, quick-lime, or salt of potash, may here be substituted for the calx of tartar. Yet the simple spirit of good *French* verdigrease, being once or twice drawn from as much salt of tartar, as it can dissolve in the cold, will leave the salt easily fusible and dissolvable in highly rectified spirit of wine.

'Tis farther remarkable, that I have gain'd an inflammable spirit from damask roses, by beating them in a mortar, putting them into a vessel, with a proper quantity of water and ale yeast, and keeping them in fermentation for five or six days; and then distilling all *per vesicam*.

I also imagine, that menstrua may be discover'd, capable of volatilizing, or unlocking the more gross and sluggish bodies, with greater ease than usual. There is a liquor, used by chymists, with which I have often distill'd spirit

of

of nitre, by a gentle heat of sand; and believe I could bring some over without any external heat at all. And having once suffer'd a certain menstruum to remain, a very little while, upon crude antimony, I afterwards abstracted it by a moderate sand-heat; when the liquor brought over not only some of the substance, in form of red flowers, and united other parts thereof to itself, but rais'd several little transparent masses, like amber, to the top of the retort; which were inflammable, and both smelt and burnt like common sulphur; and yet the menstruum, which was easily recoverable from the antimony, only tasted, before 'twas used, somewhat like good vinegar.

But, besides the several thrifty ways already mention'd, others, that are now unthought of, will, I question not, by human industry, be discover'd. The calcination of gold and silver is render'd easier by amalgamations with mercury, than by the long continued violence of fire. And to lay no stress upon the *Alkabeſt* of *Helmont* and *Paracelsus*; I doubt not but menſtrua, to facilitate difficult operations, may be found; and such as will not lose their virtue, like our common saline spirits, by being but once used. The menstruum I make by barely distilling good verdigrease, will serve several times to extract a tincture out of fresh glass of antimony.

In the last place; a naturalist may, probably, find better means of preserving chymical medicines than we now know. Clarified juices of vegetables, extracts, robs, &c. may be better and cheaper preserv'd than by sugar, if *Helmont* said true, that he was master of such an art. His way of fuming liquors with sulphur, is a good one for this purpose. But a friend of mine has a secret to preserve the fumigated juices of plants, with surprizing success; his method is to add thereto a small quantity of the white coagulum, made by the pure spirits of wine and urine.

To improve the means of preserving medicines.

'Tis tedious thus to insist upon particulars; I shall, therefore, add, in the general, that the common practice of chymists, is no rule whereby to judge of the extent of the natural skill, and mechanical contrivances, that might be employ'd to render remedies more cheap, or, which is the greatest cheapness, effectual: for of all methods to reduce the expense of a cure, the use of specifics is the best; and he who knows the true causes and seats of diseases is enabled to discover such grand remedies, as bringing immediate relief to the patient, render the physician, chirurgeon, and apothecary, unnecessary. Thus the merchant, formerly mention'd, was reliev'd, by a specific, from the gout; one young lady cured of fistulas, by millepedes; and another of an almost hereditary epilepsy, by mistletow of the oak, might severally, in the ordinary way, have, in vain, bestow'd an hundred times the money those powerful medicines cost them. But if slight medicines, or single simples, may, sometimes, perform such speedy cures, even in chronical cases; what may not be expected from the grand secrets of art and nature; when the best preparations of the noblest simples shall become known to judicious physicians, well versed in the theory of medicine, and the history of diseases? *Riverius* was none of the greatest naturalists, or chymists; yet, how many patients, according to his own

Specifics to be endeavour'd after.

The Usefulness of Philosophy.

account, did his specific relieve from quartans, which might, otherwise, have prov'd no less tedious than expensive?

The vulgar chymistry very incomplete.

But, farther, the great variety of new remedies, to be found in the shops, will shew, that natural philosophy may improve the pharmaceutical preparations of simples. I must, however, declare, upon a serious consideration, that the chymical medicines, which occur in the common dispensaries, are far from being the best that might be contriv'd. The vulgar chymistry remains very incomplete, and affords rather a collection of loose experiments, than an art built upon solid principles: we must, therefore, expect a farther improvement herein, before the noblest sort of chymical remedies become common; or considerable errors in several preparations be avoided. 'Tis not labour, but skill, that produces noble medicines. A few pregnant principles, well applied, are more useful than many furnaces and glasses.* I never knew opium so well corrected by aromatics, and the tedious operations of the fire, as by wine and salt of tartar: and that violent emetic, *mercurius vita*, is better moderated, in it's evacuating quality, by continual stirring it, in a flat glazed earthen vessel, over a fire, 'till it emits no fumes, and turns of a grey colour, than by ever such quantities of cordial liquors or conserves. And this, as I am credibly inform'd, is the *Mercurius vita purgans*, so frequently mention'd by *Riverius*. And, tho' quick-silver and antimony are, by the safe practitioners, esteem'd too churlish to be meddled with single; they may, together, be sublimed into a cinnabar; which being, alone, six or seven times resublimed, becomes a safe and excellent alterative. I once knew a particular slight preparation of salt of tartar, correct such poisons, as, I am confident, ten times the quantity of the most powerful vulgar antidotes, would not tame. The same salt, duly managed, without proving either emetic or cathartic, has been found more effectual, in many stubborn cases, than *Crocus metallorum*, *Mercurius vita*, or such desperate remedies. 'Tis a more remarkable instance, to our purpose, that chymists and physicians have not been able, with all their art, to deprive glass of antimony of it's emetic quality; yet, this may easily be done, only by digesting it with pure spirit of vinegar, 'till the menstruum be highly tinged. And, if you gently abstract that liquor, and digest well rectify'd spirit of wine upon the remaining red or yellow powder, you will obtain an excellent tincture against several diseases; which, tho' *Basil Valentine* prescribes only in a dose of five or six drops; yet a domestic of mine, out of curiosity, took thirty drops at once, without finding it emetic. And I would here have it particularly remark'd, that by bare repeated digestions and fermentations, saline and sulphureous essences, exceedingly small in bulk, and durable may be prepared, from many vegetables. Some of these I have kept above three years, and they still retain more of their

* That the obvious chymical operations may perform much more than is usually expected from them, Dr. *Langelos* proves, by several examples; as the rendering of salt of tartar volatile, and dissolving coral into a red mucilage, by digestion; rendering gold volatile, and gaining a genuine mercury from antimony, by means of trituration, &c. See *Philosophical Transactions*, No. 87. p. 5052.

respective plants than the vulgar waters, spirits, extracts, or salts hitherto extant in the shops.

And, if we may believe the ingenious chymist to the *French* king, a single herb, by pure skill, without the assistance of fire, may afford a nobler medicine, than any of the elaborate compounds, to be met with among vulgar chymists. This efficacious part of a plant, *Paracelsus* calls its *Ens primum*, whose process, for obtaining whereof, I should never have thought worth trying, but for what the experienced chymist, above mention'd, told me from his own observations: for he, as well as *Paracelsus*, ascribes a renovating power to the *Ens primum* of baulm; and assur'd me, in the presence of a famous physician, to whom he appeal'd for the truth of his relation, that an intimate friend of his, being possess'd of this preparation, made trial thereof, upon himself, by taking a small quantity every morning, in wine, for a fortnight; long before the end of which he found the nails of his fingers and toes to loosen; which, at length, falling off, insensibly, he proceeded no farther; being satisfied with these tokens which he reserv'd as a rarity. But upon giving the same medicine, for ten or twelve days, to a woman, about seventy years of age, without acquainting her with what he expected therefrom; it brought her menses down upon her again so fresh, as to frighten her, and stop the prosecution of the experiment. He added, that he, also, gave some drops of it to an old hen, for a week; and about the sixth day after, she began to moult, and continued so, gradually, 'till all her feathers dropp'd off; but regain'd new ones in a fortnight. My author, also, acknowledg'd, he had observed extraordinary virtues in the *Ens primum* of the greater *Scrophularia*.

His method was to collect the plant, at a convenient season of the year, and proper time of the day, to beat it well in a stone mortar, and place it in a bolt-head, and to digest it for 40 days in a dung-hill; after which he opens the vessel, separates the grosser parts of the liquor, and digests it in a gentle bath, that the remaining grossness may subside; then filtering the juice, he adds to it the fixed salt of the grosser parts, abovemention'd, dry'd and calcin'd. To this prepared liquor, he farther puts the liquor of good sea-salt, purify'd, melted, and suffer'd to run *per deliquium*. Then the whole, seal'd up in a convenient glass, is expos'd to the sun, for about six weeks; after which there swims on the top of it the *Ens primum* of the plant, in a liquid form, transparent, and either green or red, or, perhaps, of some other colour, as the nature of the vegetable determines.

Helmont, also, has a way, which he calls *Via media*, very different from the vulgar one, of preparing *Elixir proprietatis*, whereto he attributes prodigious effects: some, indeed, think this method fraudulent; but, with care, I have made it succeed. And the medicine, itself, is given with great success, in difficult cases, by physicians of my acquaintance.

And here I cannot but observe, from considering the various alterations which chymistry brings upon natural bodies; and the many new properties it, therein, occasions, that if we want not curiosity and industry, there must, hence, necessarily arise such a set of active and powerful medicines, as it were vain

The search after
powerful menstrua
recommended.

to hope for in apothecaries shops; and, consequently, without any great discoveries, or farther improvement of principles, chymists, such as they now are, may greatly add to the pharmaceutical part of physic. But if the operations of chymistry were strictly examin'd, and thoroughly understood, there's no question but, by a skilful application, and, especially, by a rational and orderly series thereof, many grand remedies are discoverable. Experience has inform'd me of a way, without any foreign matter, or violent heat, to reduce solid animal substances, almost wholly into a liquor, which, by a gentle fire, affords it's spirituous and saline part before the phlegm. This, I would, in a particular manner, inculcate, that were we possess'd of a few, safe, general, recoverable, and powerful menstrua, 'tis not to be known what might be done in chymistry: such, therefore, as would advance chymistry, medicine, or natural philosophy, would do well to turn their inquiries this way.

An ordinary gold-smith can now, with *Aqua fortis*, make many useful experiments upon silver and gold, which none of the same trade, who liv'd before the discovery of that menstruum, were able to do. No wonder, therefore, that *Helmont* advises his readers to learn the volatilization of salt of tartar; the spirit whereof, he says, not only dissolves crabs-eyes, silver, quick-silver, &c. but cures many diseases. And by the concurrent testimonies of judicious chymists, this salt is worth labouring to obtain; tho' their attempts have all fallen short of it. Notwithstanding this, I cannot think the thing impossible; for I, more than once, with ease, render'd, even, gold itself, volatile, and exhalable, in time, by a vehement fire; and have, from crude tartar, mix'd with two or three mineral bodies, obtain'd a large quantity of true volatile salt; which I suspect came from the tartar, tho' I must own, it was rather a volatile salt of tartar, than alkali of tartar made volatile*. This shews, however, that tartar, by an unusual management, will yield an uncommon salt. Besides, an ingenious acquaintance of mine, whom, notwithstanding my great distrust of chymists, I durst credit, affirm'd to me, that he had seen a real volatile salt of tartar; wherewith such strange things were done, that he believ'd most of what *Helmont* deliver'd concerning it. And, I am inclined to think, this salt may be made by more ways than one; tho' a good method to volatilize it seems to be by spirit of wine; the difficulty wherein is, to make them associate. Now I have, myself, brought salt of tartar to flow readily upon a hot iron; to take fire, to flame, and when smartly dry'd, to dissolve in highly rectify'd spirit of wine.

And, tho' many learned men are pleas'd to determine what can, and what cannot, be obtain'd in chymistry; no one should be, thereby, discouraged from searching after these noble menstrua. To my knowledge there is now in being, a kind of menstruum, of a pure crystalline substance, made by fire,

* That judicious chymist, M. *Hamborg*, has discover'd a way of volatilizing all manner of fixed salts. This he teaches by an example in his process, for making his volatile narcotic salt of vitriol, from the *Caput martium*, after the oil is distill'd off. See *Memoir. de l'Acad. A. 1702. p. 66.*

as truly saline as salt of tartar; which, tho' well purified, perfectly volatile, and easily soluble in rectified spirit of wine, as well as common water, and with either reducible to a noble menstruum, is yet actually sweet to the tast. And, notwithstanding the vulgar saline menstrea, have actions contrary to each other, so that what an acid one dissolves, an alkaline, or urinous one, precipitates; I have found, that a red tincture of glass of antimony, drawn with a menstruum much lower than the former, could not be precipitated, either with spirit of urine, or an alkaline solution. Nay more, it readily mixed, both with these, and strong acid volatile spirits, without the least ebullition, or visible effect.

We took several ounces of highly rectify'd spirit of fermented urine, made *per se*, and pour'd it upon as much new filings of steel, as, we guess, would, at least, suffice to satiate it fully. These we put in a moderately warm place, where the menstruum wrought on the metal for several hours together, and dissolved a considerable part of it. This solution we set to filter, and found it of a tast considerably strong, but very different from any of the chalybeate preparations, we had seen made with acids. The liquor being kept in a stop'd viol, for some days, near a window, did, in the cold, let fall, by degrees, a considerable quantity of powder, of a deep green colour, tho' the liquor itself was not of that colour; however, the superficial part of what remain'd in the filtre, did, also, in the air, turn green. But tho' our solution, pour'd off from the subsided powder, was warily and slowly evaporated, we did not find it would well crySTALLIZE. What use may be made, in physick, of preparations of this kind, I leave those of the profession to judge.

The body of steel open'd in an extraordinary and uncommon manner.

To render steel volatile by a menstruum, not so corrosive or dangerous to the body, as oil of vitriol, or spirit of nitre; I pitch'd upon good spirit of sea-salt, and in several ounces of this liquor, dissolved, as much as we easily could, of choice filings of fine steel; and having filter'd the green solution, we very slowly evaporated it in a glass vessel, and took such care not to spoil the matter, that we had plenty of fine green crystals; most of which we put into a small strong retort, and, by degrees, of fire, and a strong one, at the last; we obtain'd many ounces of a liquor that came over in white fumes, like mists driven by the wind, and afforded a sulphureous smell. This liquor we rectify'd, and had a yellow ponderous spirit, that seem'd much nearer allied to the spirit of sea-salt, than to the common oil of vitriol; especially, since being mixt with *Aqua fortis*, it would, like spirit of salt, make it, even without heat, dissolve leaf-gold.

But having put into a little of it, already made yellow, by dissolving leaf-gold, a very thin plate of gold, the menstruum made it look all over white, almost like silver; which seem'd to argue, that this vitriolate liquor differ'd from common spirit of salt.

But the dry part, elevated by the force of the fire, we found to be distinguishable by its situation, and more durable accidents, into three kinds of substance; whereof one was almost like a powder, which, after touching the air, did, in a while, come to be of a yellow colour, almost like sulphur; but it was not, indeed, truly combustible sulphur. The other substance consisted

The Usefulness of Philosophy.

of larger parts, and was of a deep colour, between red and brown. But the third, which seem'd the largest of all, was made up of fine parts, bigger than the former, of a deep reddish colour, and adorn'd with a fine gloss, like that of scales of fishes. The *Caput mortuum* was of a surprizing texture; for a great part of it appear'd to be turn'd into a talky substance, consisting of very thin broad plates, smooth and glossy, lying upon, and against one another, like those that make up *Muscovy* glass, when the pieces are more thick than large.

*Gold debas'd by
an anti-dissolv.*

Weighing two drams of gold, I caus'd it to be cupell'd with a sufficient quantity of lead, and quarter'd with refined silver, and purged *Aqua fortis*; then having brought the gold to fusion, in a new crucible, carefully nealed, with the help of any addition; I put to it a small quantity of a powder, communicated to me by a stranger; and continuing the metal a quarter of an hour in the fire, that the powder might diffuse itself through it; we pour'd the metal into another crucible, gradually heated before to prevent cracking; where it was observ'd, at the first, to look like pure gold; and, afterwards, like an opal, for some time; yet, when cold, it appear'd to be a lump of metal of a dirty colour, and, as it were, over-cast with a thin coat, almost like half vitrified litharge. To one side of the crucible a piece of metal stuck, almost like silver; and the bottom was over-laid with a vitrified substance, one part of which was transparent yellow, and the other of a deep brown, inclining to red; in which were five or six little globules, that look'd like impure silver. Having rubbed this metal upon a touch-stone, between gold and silver, the mark it left was more like silver than gold. 'Twas brittle, and being knock'd with a hammer, it flew into several pieces. The inside resembled bell-metal more than gold or silver. A dram of it, with about six times its weight of lead, being put upon a well nealed cupel, emitted fumes, plentifully, for an hour and a half; and when the operation was ended, we found the cupel smooth, intire, and tinged with a fine purplish red; and, besides the refin'd gold, there lay upon the cupel some dark colour'd recrements, which we judg'd to be base metal, but not lead. The gold being weigh'd again, had lost seven grains in weight, which was made up by the recrement, whose weight and fixity were surprizing.

The dirty colour'd metal, being hydrostatically weigh'd, instead of proving nineteen times as heavy as an equal bulk of water, it's proportion was but as fifteen, and two thirds to one; whence it appear'd that the gold was really debas'd, since it lost, considerably, of its specific gravity, an essential property.

From hence it appears, that an operation, almost as strange as that called projection, may safely be admitted; since this experiment shews, that gold, which is so homogeneous, and the least mutable of metals, may, in a short time, be exceedingly changed, as to malleableness, colour, homogeneity, and specific gravity, by so small a portion of matter, that this powder transmuted a thousand times its weight of gold.

I now proceed to shew, that chymistry and philosophy, as they supply us with medicines; so they may also greatly improve the *methodus medendi* itself. Medicine is so difficult, and so many things are necessary to a complete skill therein, that 'tis no scandal to physicians to suppose it improveable. *Hippocrates*, says *Paracelsus*, justly complains of the shortness of life, and the tediousness of his art; and *Celsus* scruples not to call physic a conjectural art. No wonder it should be hard to acquire, when the two great instruments of discovery in all arts, judgment and experience, are here, according to *Hippocrates*, difficult and dangerous. Many others, also, declare, that the difficulties, of becoming a good physician, are almost insuperable. 'Twill, therefore, be the less surprizing, if we attempt an innovation in the curative part thereof; especially, since I have observ'd the method of the best reputed physicians, in *England*, to be repugnant to each other. It certainly deserves an impartial enquiry, whether the new discoveries made in anatomy and the doctrine of diseases, ought not to alter and correct the old *methodus medendi*. Be this as it will, the uncommon efficacies of some new remedies may shorten the cures of diseases, by answering many intentions at once. Thus the simple, I formerly mention'd, cured the king's-evil, without any other assistance; and thus phlebotomy is a remedy for the pleurisy: tho' we have known it cured, even in young persons, by chymical medicines alone. The rickets, supposed a new, and almost incurable disease, now commonly yields to *Ens Veneris*; tho' its operation be scarce sensible; bating, that at first it often proves diaphoretic. This gentle property, methinks, might lead physicians to consider, whether they cou'd not frequently relieve their patients, without those large and troublesom evacuations they usually prescribe. For, the peccant matter is commonly small in quantity, and might, were we masters of specific remedies, be either breath'd out by insensible perspiration, or carried off by sweat or urine; without causing farther uneasiness to the patient. Great cures may be perform'd by bare external applications. Learned men assure us of the efficacy of the *Lapis nephriticus* against the stone, being bound upon the wirts; and not only *Boetius de Boot* highly prizes it, but the famous *Monardes*, declares he has seen its great effects upon persons of quality; which yet fall short of what the learned *Unzerus* tells us about it. We must own, however, that some stones, which go under this name, have been unsuccessfully applied in nephritic cases: but it seems, that many of them, tho' not sophisticated, want this virtue, and are scarce, otherwise than by trial, distinguishable from those of the good sort, which are usually greenish. *Garcias ab Orta* mentions a stone found in *Balagar*, called *Alaqueca*, that wou'd immediately stop any hemorrhage: and *Monardes* relates great virtues of another, against hysterical disorders. He also tells us, upon his own knowledge, of a blood-stone, found in *New-Spain*, that wou'd even stop the menses, by being worn in a ring; and *Bontius* says of the *Lapis porcinus*, that it will cause abortion, and bring down the menses, by being held in the hand. *Helmont* affirms he cou'd prepare a metal, whereof a ring being made, and worn, wou'd give instant relief in the hemorrhoids, and absolutely cure them in four and twenty hours. He likewise commends it in suffocations of the uterus, &c. And if we may believe *Paracelsus*, he had a ring of still more surprizing virtue. But to come

That chymistry and philosophy may improve the *methodus medendi*.

The Usefulness of Philosophy.

to other external remedies, *Fabritius ab Aquapendente* assures us, he cured a schirrous spleen, and the dropfy, by a continued use of sponges dipp'd in common lime-water; and placed near the part affected. Add to this, the strange cures related by *Kircher*, the like whereto have been confirm'd to me by eye-witnesses thereof, concerning the cave, near *Rome*, wherein the patients being exposed naked, and thrown into a sweat, either thro fear, or the sulphureous vapours of the place; are licked well by the serpents of the grotta. And do we not often see agues cured by amulets, and pericarpia? I my self, after the usual remedies had proved ineffectual, was cured of a violent quotidian, by applying to my writs a paste made only of bay-salt, new hops, and blue-currants; which has, also, reliev'd many others both of quotidians and tertians; and done good service in continual fevers.

That external remedies shou'd be farther tried.

I cannot help wishing, that physicians had been more curious, in trying the effects of external applications; for, the subtil effluvia of some bodies seem, by this means, to insinuate themselves, without alteration, into the mass of blood; and to have the same virtues as the body itself internally used. Thus it happens in some preparations of sulphur; but more manifestly in cantharides and quick-silver. I was lately told, that by washing a child's scabby head with a decoction of tobacco, he was intoxicated, and made sick; and that cathartics, externally applied, will operate. There are other medicines which, before they get into the blood, receive great alterations from the stomach, &c. and may therefore have different effects, when externally applied. Thus it happens in the just mention'd instance, tho' neither the hops, bay-salt, or currants, taken inwardly, are noted for any febrifugal virtue. So likewise turpentine and soot are internally prescribed in nephritic and pleuritic cases; but externally, in pericarpia, against agues: and yarrow, besides its other virtues, being worn in a bag, on the pit of the stomach, was the grand secret of a curious nobleman, in the same distemper. A very famous physician, also, assured me he had used it in the like cases, with strange success. The chilblains, when they come to break, have been often cured by barely strewing thereon powder of dried quinces. And who knows what effects other bodies, outwardly used, may produce, were experiments properly made to discover them? The internal operations of some things, are directly contrary to their external. Spirit of wine, applied outwardly, allays inflammations on the surface of the body; which, if it were drank, wou'd inflame: and the poisonous juice of the root mandihoca, *Piso* tells us, is good for sore eyes. Besides, were the simples, design'd for external application, skilfully prepared, it might greatly improve their operations. Vitriol, which is copper, or iron, corroded and fix'd by acid salts, has virtues not to be found in those metals when crude. Gold dissolved in *Aqua regis*, and precipitated by oil of tartar, is, taken at the month, a gentle purgative; but the same preparation, calcined with flowers of sulphur, becomes diaphoretic. And tho' the external virtues of this medicine be not much commended, 'tis probable they are very great, and different from those it has when used internally. I knew a person greatly afflicted with ulcerated hemorrhoids, who applied thereto an ointment, that chiefly consisted of this *Aurum fulminans*; and tho' at first it occasion'd excessive pain; that soon abated, the hemorrhoids closed

closed the day after, and totally disappear'd on the following; nor has he now, for several years, had any relapse. The physician, who accidentally directed this, assured me, he had found strange effects therefrom in venereal ulcers. The phlegm of vitriol, and *Saccharum Saturni*, which, given internally, are said to cool the blood; and externally applied, to cure burns and inflammatory tumors, do both, nevertheless, disperse cold swellings.

A famous chymical writer assured me, his child was so strangely and desperately affected, that he concluded him bewitch'd; but upon suspending the *Electrum minerale immaurum Paracelsi* about the child's neck, so as to touch the pit of his stomach, he immediately went to rest, which he had not done for many days before; and, waking, cry'd for the breast, and, from that time, suddenly and surprizingly recovered. I am not forward to credit relations about witchcraft; but let what will be the distemper here, 'tis plain that a cure of a bad case was soon perform'd by the external application, even of a mineral substance.

Boetius de Boot records some very remarkable effects of the blood-red jasper-stone. "Tho' I am not fond," says he, "of attributing extraordinary virtues to gems, yet am I an eye-witness to some strange effects of the jasper. A maid having her menses continue so obstinately, for some days, that nothing cou'd put a stop thereto; I order'd her to bind a red unpolish'd one to her thigh, which immediately cured her. Another person, receiving a wound in his foot, there ensued such an hemorrhage as we cou'd by no means restrain, till this stone was applied; which instantly stopp'd it, tho' the wound remain'd uncover'd." But the most surprizing relation he gives us, is concerning the maid at *Prague*, who had a vehement hemorrhage continue upon her, several times in a week, for six years together; and no remedies reliev'd her. Our author, therefore, lent her an experienc'd jasper, which when she hung about her neck, the flux of blood immediately ceased. She afterwards wou'd, out of curiosity, lay aside the stone; when, the hemorrhage, in a few weeks, constantly return'd; which she as constantly stopped by putting it on again. At length, however, she was quite cured hereby.

The experienc'd *Henricus ab Heer* mentions a still more surprizing effect of an appended remedy. He tells us, that a woman who had, by an unskilful midwife, her bladder so lacerated, that she was subject to a perpetual diabetes, found a cure by wearing, as a gypsy taught her, a little bag hung about her neck, wherein was included the powder of a toad burnt alive in a new pot. I the rather mention this, because the author found the same effectual upon a merchant, who was left, in a like condition, by an unskilful lithotomist; and because, recommending this odd remedy to the tryal of a curious physician, he told me, tho' it had failed in one or two instances, it had succeeded in two or three. He added, that in one, whose distemper proceeded from a dilaceration of the bladder, the remedy did service, as long as she wore it about her, and kept it renewing, as its virtue diminish'd; but that if she left it off a while, the distemper return'd.

Henricus ab Heer, also, tells us of a lady, a patient of his, whom he supposed bewitch'd, and thought incurable, till he met with an unguent, in *Carrichter*, a Dutch author, extoll'd for this purpose, which proved effectual. I my self have met with the prescription, in this author, set down a little different from what I

The Usefulness of Philosophy.

find it in the former. The mistletow of the hazel, an ingredient herein, which *Henricus ab Heer* found great difficulty in procuring, is not so scarce in *England*, being very green and extremely bitter; I, therefore, with those who have opportunity, wou'd make trial thereof; for besides the above-mention'd authorities, a learned physician highly commended it to the judicious *George Horfins*.

*Diseases cured and
caused by frights.*

Now, tho' we suppose these cases not to be supernatural, or the effects of witchcraft, there must be a wonderful efficacy in an external remedy, to cure, by barely anointing the limbs therewith, such radicated disorders, with their horrid train of symptoms. 'Tis the less strange, therefore, what *Helmont* says of a plaister, wherewith he, infallibly, cured even autumnal quartans, and prevented a relapse, which was composed only of a few resolving and absterfve ingredients; he adds, indeed, that it succeeded more slowly in fat persons. And yet, in these approved methods of curing distempers, there is no sensible evacuation made of the peccant matter, which, perhaps, still remains in the body; being only deprived of its former qualities, by the effluvia of these remedies, and thereby rendered so far obedient to nature, as to be thrown off, if necessary, either by sweat, urine, or insensible perspiration. That a disease may, sometimes, seem to be removed, whilst the peccant matter is lodg'd in the body, appears from the cure of agues by a sudden fright; wherein no discernible evacuation is made; tho' probably some change in the fluids, or texture of the morbid matter, be thereby occasion'd: this seems confirm'd by many instances already produced. I knew a courageous officer in the army, who was strangely fearful of rats; and having been long tormented with an obstinate quartan, he carried it with him into several countries, without finding a cure. Coming at length, by accident, into a room, where an huge rat being up in a corner, and cou'd not, otherwise, escape, furiously leapt upon the gentleman; which put him into such a fright as freed him from his distemper. *Salmuth* relates a pleasant cure, even of the gout, by a fright. A gouty person having his feet and hands wrapp'd up in a cataplasm made of turneps, flower and milk, happen'd to be left, alone, in his chair, when a sow, invited by the scent of the ingredients, came into the room; and, endeavouring to get at the poultis, overthrew the gentleman and his chair; which put him into such a fright, that his pains decreas'd, that very day, and afterwards, continuing to diminish gradually, they at length totally left him, and never return'd.

A woman, of a middle age, told me, that taking her son, a little boy, whom she was dotingly fond of, with her, to a river-side; whilst she was busy, the child stole away from her, and walking along the bank, he chanced to fall into the river: in the mean time, the mother, missing her child, hastily cast her eyes towards the brink of the river; and, not seeing him there, presently concluded him drown'd; and, upon that, was struck with so much horror, that, among other mischiefs, she fell into a dead palsy, of her right arm and hand, which still continu'd, notwithstanding all she cou'd do to remove it.

I familiarly knew a gentleman, who, when he was a youth, fell into a violent and obstinate sciatica, which continu'd with him so long, as to leave him little hopes of relief; but the devotion of his friends caused him to be carry'd, since he could not go, to church upon sundays; and here it happen'd, that the town being a frontier garrison,

garrison, there was occasion given to a very hot alarm, that the enemy, being got into the town, was advancing towards the church, to massacre all that were in it. This so amaz'd and terrify'd the people, that, in very disorderly haste, they all ran out of the church, and left my friend in his pew; who, being no less frighted than the rest, forgot his disease, and made a shift to get off, and follow those who fled; but it quickly appearing, that the alarm had been false, his friends began to think in what a condition they had left him; and hastening back to help him out of the pew, they, to their great surprize, found him in the way upon his feet, and walking as freely as other men. When he told me this story, it was above forty years since the thing happen'd; and in all that time, he never had one fit of the sciatica.

There are various instances of great changes produced in the body, when nothing has been receiv'd at the mouth. On the other hand, a good air, alone, does frequently, in consumptions, and other diseases, perform what was, in vain, expected from physick. 'Tis pity, our *European* physicians shou'd want the physick books of *China*. The famous Jesuit *Samedo* informs us, that the writings of our physicians having not yet reach'd *China*, physick is there learnt from their own numerous authors. And tho' phlebotomy be not practis'd, either there or in *Japan*, and tho' they use neither cupping, nor issues, syrups or potions, and nothing but simples; yet physick, says our author, is in a very good state among them; and, accordingly, he gives us some considerable instances of their skill therein. 'Tis true, their physicians are, in point of learning, much inferior to ours; but, methinks, 'tis somewhat extraordinary, that in so vast, civilized and populous a country, physick shou'd be successfully practis'd, without the use of those evacuations, which are so frequent among us. 'Tis, also, probable, that medicinal knowledge is greatly improveable, by more curiously observing the practice of midwives, and barbers, the good women, and empiricks, with the rest of that illiterate crew, among our selves, who presume to meddle with physick; as well as of the *Indians*, among whom the generality of men are so ignorant, as to live without physicians. For where physick is practis'd without any knowledge of the art, many things are rashly done, which may afford good hints to a judicious observer. Not to mention, that where physicians are illiterate, specifics generally flourish; for, such persons, for want of skill in pharmacy, and knowing how to vary their remedies, as circumstances require, almost wholly rely upon specifics; the virtues whereof are usually more observable in their practice, than in that of more skilful artists; because empiricks having their sole dependance upon these, they try them to the utmost, without mixing, as is too common, other ingredients therewith; which, as *Galen* well observes, will render it difficult to determine what it was, in the composition, that did either good or harm.

Bontius tells us, 'tis undeservedly, that the *Europeans* esteem the *Indians* as barbarians. He says, the most unlearned among them have a perfect knowledge of plants. *Linchoten*, also, says, that the physicians of *Goa*, not only cure those of the natives, but the *Portuguese* themselves: he adds, that the vice-roy, with the arch-bishop, and all the ecclesiastics, put more confidence in these, than those of their own nation. In confirmation hereof, I might alledge the practice of the uncivilized *Irisb*, and some other countries, where profess'd physicians are

unknown.

The Usefulness of Philosophy.

unknown. But, as *Celsus* says, “this art is practised universally, and the most ignorant nations have their plants and remedies for wounds and diseases.” I, therefore, wish, that others would imitate the example of *Prosper Alpinus*, who wrote the *Egyptian* practice of physic; of *Bontius*, who treated of the *Indian*, and of *Piso*, who, lately, gave us the rude method of the *Brasilians*; wherein he tells us, there are many things, which may instruct the most learned physician: and, according to the saying of our great *Harvey*, “there is no nation so barbarous, but, either by accident, or absolute necessity, may find something of use to mankind, whereof the politer nations are ignorant.” Nor should we despise remedies found by ignorant people, because they know not our theory of physic. The empirics, in *Celsus*, wittily said, “does reason agree with, or does it contradict experience? if the former, ’tis superfluous; if the latter, ’tis false”. Let useful remedies come from what quarter soever, they are not to be rejected; be the ignorance of those who present them, ever so great, or their opinions ever so contrary to ours. “Reasoning, says *Celsus*, has nothing to do with physic; the defenders of opposite opinions may cure diseases alike; and this, because they, therein, follow not their own obscure hypotheses, but experience, that gave birth to the art”. This passage, indeed, ascribes too little to reason, yet there is something remarkable in it; especially, if we consider, that the late discoveries of the motion of the chyle, and lymphatic juice, hath not yet enabled men the better to cure diseases. Anatomical discoveries may, perhaps, in time, greatly conduce to improve the curative part of physic; yet this observation may give us a caution against relying upon the disputable opinions of physicians, so far as to condemn all the practice that does not square therewith. Our author says well in this case, “disputation may be here continued for both sides of the question, where wit and eloquence, at length, will carry it; on the contrary, ’tis not oratory, but remedies, that cure distempers.” It wou’d be tedious here to cite all the authorities I am able, to confirm the efficacy of external remedies; there is one, however, that must not be omitted: ’tis in a letter written from *Pernu*, by *Petrus de Osma* to *Monardes*. “There was an *Indian*, in the city *Posito*, where I resided, several years, who cured all distempers by the juice of a single plant, rubbed upon the affected parts. By covering his patients up close, he caused them to sweat, when pure blood wou’d flow from the places whereon the juice was rubbed; this he wiped off with linen, and continued the operation, as long as he thought proper; in the mean time supporting them with a nourishing diet. By this means, many desperate cases were cured; and so well too, that the patients seem’d to be thereby render’d stronger and younger: but we cou’d not, by all our art, prevail upon him to discover to us the plant.”

Magical cures to be enquired into.

There is another sort of external remedy, which pretends to operate in a still more wonderful and extraordinary manner; whereinto it might be proper, cou’d we avoid credulity, to enquire. And it might, perhaps, deserve an experiment, to see whether such cures, as vulgarly pass for fabulous or magical, are actually performable: such are those reported of the weapon-salve, and sympathetic powder, &c. said by chymists to be perform’d, either by magnetism or transplantation. Nor is it only by the vulgar that such cures are thought possible, for I find

find them used and recommended by many eminent physicians. I know not what to think of the sympathetic powder; but a very honest gentleman, well known to the learned world, by his writings, complaining to me of an ulcer in his bladder, which was continually exasperated by the sharp medicines he took, in hopes to dissolve a stone in that part; I advised him to try this powder upon some of the matter voided with his urine, since no danger cou'd attend it. Soon after this, I had thanks, for my advice, both from himself and his physician; for he was eased of the pain of his ulcer, and so continued for above a year; how much longer I know not. But I lay no stress upon this, nor the testimonies and relations of *Paracelsus*, *Helmont*, *Goclenius*, *Servius*, &c. who professedly write in defence of the weapon-salve; upon account of some trials I my self have made, both upon that, and the sympathetic powder; tho' I cannot but say, I have sometimes found them available; and seen something follow upon the use of the latter that inclin'd me to think it might, sometimes, perform cures. But to produce less exceptionable authorities. *Dominicus Panarola* tells us, "wonders are, every day, discover'd in physick; which confirm what *Servius* delivers of the weapon-salve: that the menses are stopp'd by a rag dipp'd in the matter excreted, and placed under hot ashes, has been frequently experienced; and *Castellus* declared he had found, that if the hemorrhoids were touched with the bulbous root of chondrilla, they dried away, if the root were dried, but rotted if that rotted; for which reason, after being thus used, it was put to wither in a chimney." The learned *Salmuth* gives us an example of a violent pain, in the arm, removed by transplantation. The way was this: red coral, beat up with oaken leaves, were kept to the part affected till suppuration; then, in the morning, this mixture was put into a hole, bored with an auger, into the root of an oak, on the east side thereof, the hole being stopped up with a peg, made of the same tree; and from that time, the pain entirely ceased; but upon taking out the amulet, it return'd sharper than before. A great lady, far from being credulous, confess'd to me, as did also some of her servants, that, with the common remedy of ash ashes, form'd by warm urine, into seven or nine cakes, and buried for some days in a dunghill, she was cured of the yellow-jaundice, after passing through a tedious course of physick, in vain prescribed her for it, by the most famous physician in *England*; and afterwards, relapsing into the same disease, it was again removed by the same means. A physician, also, told me, that having been long afflicted with an obstinate marasmus, which prevailed upon him in spite of all the remedies he cou'd use; at length, he resolved to try a sympathetic, which I have found in *Hartman*. He boiled an egg, till 'twas hard, in his own warm urine, and with a bodkin perforating the shell, in many places, he buried it in an ant-hill, where, as the emmets devoured it, he found his distemper lessen, and his strength encrease; so that at the time he related this, he thought himself well. *Rivcrius* tells us, that the daughter of a great officer in *France* was excessively tormented with a whitlow, for four days together; for which he order'd her finger to be put into a cat's ear; and, within two hours after, she was freed from her pain, and the whole hand, which was tumified, came to its natural size, except the finger. The same author relates, that a counsellor's wife, after being four days tormented with the like, was cured by the same remedy, within a quarter of an hour.

The Usefulness of Philosophy.

hour. 'Twas remarkable, that, in both these cases, the cats gave such manifest signs of pain, that *Riverius* thought they attracted the morbid matter of the patients. But *Peter Borelli* declares, that even the pain of the gout is greatly eased by admitting whelps to lie, in the same bed, with the person afflicted; and affirms, they thereby contract the distemper, so far as to go lame. Perhaps, this author was induced to write thus from the report, that *Fludd*, the chymist, had by this means transplanted the gout from one of his patients; the dog being afterwards subject to such periodical fits, as formerly afflicted his master.

Discourfing upon this fubject, lately, with a judicious perfon, well skill'd in phyfic, and made eminent by his learned writings, he acquainted me with a cure, by transplantation, perform'd on the fon of one who ufed to make chymical veffels for me. The obfervation being confiderable, and to avoid miftakes, I defired it in writing, which he gave me as follows. " *N. N.* of *N. Potter*, had " a fon, who was long fick of the king's-evil, which fwelled much, and broke " into fores at laft, which he cou'd by no ordinary means heal. The old man " had then a dog, which took an ufe of licking the fores; which the dog con- " tinued fo long, till he wafed the very kernels of ulcers that were knit in with " the veins, and perfectly cured the fore; but had the fwelling transplanted to " himfelf, fo that he had, thereupon, a great fwelling, that arofe and continued in " his throat. The lad was thereby freed, fo continued to be till 1660, and, " for ought I know, is fo this day. This I faw, being there at that time, to " view the clayes, and befpeak retorts of the old man."

And *Bartholin* relates, that a dog, having relieved his uncle from the colic, by being placed upon his belly, afterwards vomited violently. He adds, that a fervant of the fame perfon, having the tooth-ach, found eafe by applying the fame dog to her cheeks, whilft he discover'd manifef signs of pain; and, alfo, that the fecretary found the like fuccefs, in a fwell'd neck. Nay, Sir *Francis Bacon*, himfelf, folemnly records the manner how he was freed from a great number of warts, by a piece of lard with the fkin on, which, after having rubb'd upon them, he expofed, out of a fouth window, to putrefy. And, therefore, tho' the vanity and fuperftition of thofe who treat of magnetic remedies, together with the impertinent circumftances ufually prefcribed, along with them, do ufually, with juftice, render them fufpected by sober men; yet the inftances here produced, whereto others might, alfo, be added, join'd to the teftimonies of phyficians, and others, who either perform'd, or were eye-witneffes of fuch cures, it feems proper, that farther experiments, of this kind, fhould be rigoroufly made. I cannot but commend the curiofity of *Dr. Harvey*, who did not fcruple to try, frequently, the experiment, mention'd by *Helmont*, of holding the hand of a man, dead of a lingering difeafe, upon tumours or excrefcences, in order to cure them; which, the *Dr.* told me, he had, fometimes, found insignificant, but often effectual. Nor, if a fingle experiment, of this kind, fails, does it follow, that it ought to be totally rejected; becaufe, if they fometimes fucceed, that fufficiently fhews there are medicines, in nature, which operate after that extraordinary manner. And why fhould we expect that remedies which operate, at a diftance, or only by their effluvia, muft be more infallible than thofe taken in at the mouth? If rhubarb be an excellent medicine in diarrheas, notwithstanding the ufe whereof, vaft numbers are daily fwept away

way in *Ireland* by that distemper; if mercury be effectual in venereal cases, tho', according to *Fernelius*, *Montanus*, and others, it seldom cures them; and, lastly, if diaphoretics are justly esteem'd by physicians, tho' few, if any of them, will cause sweat in all bodies; why may not, remedies, which operate, as it were, by emanation, deserve the names of medicines, if they, sometimes, unquestionably succeed; and be try'd as such, when they are so exceeding safe and innocent?

But it may here be demanded, how a naturalist can contribute to advance these methods of cure, without evacuations? I answer, 'tis no new thing for naturalists, who are no profess'd physicians, to treat of this subject; and that they may afford good hints to one who is; not only, by the ways already mention'd, but, also, by trying, upon brutes, variety of unexperienced medicines, and communicating the success thereof. *Periculum faciendum est in vili animâ*; we may, therefore, inflict wounds upon dogs and monkeys, and give them poisons, purposely to try the efficacy of the weapon-salve, and sympathy-powder. And some of my friends assure me, they have cured lame horses, by sticking the nails, that did the hurt, into the weapon-salve; which they carry about them, for that purpose. When cattle are afflicted with the turning-evil, or sturdy; a disease that causes them to turn, frequently, round in the same place; the common remedy in *England*, is to throw the beast down and bind him; then to open his skull, and take out a little bladder, which, usually, lies near the membranes of the brain, fill'd with water and blood; and then gradually heal up the wound. And this method is much commended by our experienced *Markham*. In goats, likewise, which are subject to the dropsy, the husband-men make a slit under the shoulder, and let out the water. Various other hazardous operations in chirurgery, as arteriotomy, the extirpation of the spleen, &c. either were, or ought to have been, first practis'd upon brutes; and by proceeding, in this manner, 'tis probable, that many useful discoveries may be made in chirurgery. To pass by the known practice of spaying swine and bitches; some experienc'd shepherds have a particular way of castrating male sheep, especially, when grown so old, that the common method is unsafe. The operation is call'd swigging; and they perform it by throwing the creature on his back; in which posture he is held by a strong man, while another draws a string, as tight as possible, about the testicles; and fixing it there, they anoint the part with fresh butter, and leave the ram to feed; and in two or three days the testicles grow so rotten, as to fall off with the string, or to be pluck'd away by a small force.

From the practice of farriers, shepherds, and graziers, many things may be drawn to enrich, or illustrate, the methods of cure in human bodies; for their ignorance and credulity, with the meanness of the creatures they practise upon, lead them, to venture, in horses and cattle, what physicians dare not upon men and women. Some of these extravagant experiments have, however, succeeded so well, as to deserve the consideration of the most skilful physicians. And, methinks, some of them might, without any disgrace to their profession, oblige the world by collecting and digesting all the approv'd experience of farriers, graziers, butchers, and the like. The ancients did not despise such an employment, but honour'd it with the titles *Hippiatrica* and *Veterinaria*. To give one example of the

To make medicinal experiments, upon brutes is recommended.

The Usefulness of Philosophy.

the service this might do to the art of healing, I chuse to instance in the cure of the staggers in horses, by bleeding. I have seen a coach-horse ready to drop down dead, of this disease, on the road; but upon well rubbing his gums, with the coach-whip, 'till they bled, he was instantly relieved, and enabled to perform his journey.

We must next observe, that physic anciently belong'd to the naturalist, according to that remarkable passage of *Celsus*: "physic," says he, "was originally esteem'd a part of philosophy; and the cure of diseases grew up with the study of nature: indeed, the naturalists stood most in need of it, who exhausted their vigour in lucubrations". He adds, that many philosophers were, also, physicians; and that *Hippocrates* was the first who made a distinction between them. And this we suppose a sufficient apology for the present discourse.

Reasons for the
use of specifics.

Now the reason why physicians reject, or deride the use of specifics, being because they seem to operate in a secret and unknown manner, and not by visibly evacuating the peccant matter; a naturalist may remove this objection, by shewing, that there are similar effects in nature; and, consequently, that these ought not to be rejected, as impossible. 'Tis certain, that the school-philosophy does great disservice to physicians, by leading them into gross conceptions of nature's manner of working; and hence it is, that many learned men, among them, never expect any great effects from remedies that fall not under the senses, nor evacuate any sensible matter; whereas very great alterations may be wrought in a body, especially, if fluid, by the intestine motion, alone, of the parts. How much an imperceptible avolation of a few subtile parts of a liquor can alter its nature, we may guess by the obvious change of wine into vinegar. In *England*, indeed, by reason of the coldness of the climate, this degeneration is not so sudden as in hotter countries: but in *Brasil*, *Piso* informs us, that the express'd juice of the sugar-cane, which, by coction, would soon be brought to sugar, will, of itself, keep sweet but four and twenty hours, when it begins to grow sour, and become unfit for that purpose, but proper for vinegar. The same thing is, also, confirm'd, by travellers, of some other liquors in the *West-Indies*. But *Linschoten* tells us, of a much more sudden change in the *East-Indies*. "The sura, or juice of the coco-tree," says he, "if it stand but an hour in the sun, becomes very good vinegar, and the *Indians* use no other". That noxious liquors, (and why not peccant matter in the body?) in like manner, change their nature, appears from what we formerly observed of the juice of mandihoca; which, tho' poisonous when first express'd, purges itself, in a few hours, and becomes wholesom. That the bare admission of some subtile and invisible matter, may raise such intestine commotions in fluids, appears from the frequent souring, or spoiling of liquors by thunder: and, at *Geneva*, I remember, the inhabitants complain'd, that much of their wine was turned sour by an earth-quake.

That such invisible corpuscles may fly from amulets, or other external remedies, into the blood and juices; and there produce considerable changes, will not appear strange to him who considers, according to *Hippocrates*, how perspirable a living body is; and that vegetable and animal substances may well have such exhalations, since, even, minerals are not without them. Sulphur, and am-
ber

ber are made, by friction, to omit odorable steams; glass of antimony, and *Crocus metallorum*, impart an emetic quality to fluids, without sensibly losing of their bulk and weight; and quick-silver, in the same manner, communicates the virtue of destroying worms, to wine or water, by being only shook with them. I have wonder'd how, many learned physicians, among the moderns, either out of an affected severity, or, perhaps, animosity, against the chymists, could express a contempt of all operations of this nature; since *Galen* himself, not only confirms, the like doctrine by his reasons and authority, but delivers a surprizing example thereof, in piony-root; which he, by repeated experiments, satisfied himself, cured a lad of an epilepsy, by being hung about his neck; for the distemper; return'd if this were taken off. And this effect he accounts for from the effluvia of the root. Nay, to me it seems not impossible, that invisible bodies, by passing thro' more gross ones, should so far change the motion, or arrangement of their parts, as to produce lasting alterations in their textures; for the fluid body of quick-silver has, sometimes, without any sensible increase of bulk, been so coagulated by a metalline exhalation, that it might be cut like lead; and this solidity it will retain, 'till it be, by some art, reduced to it's pristine fluidity. One might be induced to think, that iron has a permanent alteration made in it's texture, by holding a needle, long, near the pole of a vigorous load-stone; whereby the magnetic effluvia will so dispose the parts of the nearest extremity, as to admit the steams which come from one of the poles of the stone; whilst, by holding it to the contrary pole of the same, the texture of the needle will, presently, be quite otherwise disposed: and, by changing the poles of load-stone, we have made it appear, that such alterations are possible in stones. Iron may, by different management after 'tis heated, be render'd either soft or brittle: and 'tis observed, that glass acquires a more, or less brittle texture, according as it is baked; for if glasses are carried into the open air, immediately after they are blown, and not set to cool, gradually, in an oven, they become brittle, and very apt to break: and whatever be the cause of this, 'tis evidently no gross, or visible matter.

That in a human body, likewise, great changes may be made by very subtle effluvia, appears from other things, as well as external remedies. Thus some are purged by the bare scent of a potion; as the physician of *Plymouth* assured me from his own observation: and *Salmuth* gives us an instance, where one, in this manner, operated better upon a young gentlewoman, than it did upon her sister who took it. The same author says, that *Dr. Pfeil*, when he wanted a purge, would go into the apothecary's shop, where purging electuaries were preparing, the scent whereof would work as well with him, as a dose of the medicine*. *Henricus ab Heer* tells us of a woman who used to purge herself with beef-broth; but, having broke her leg, used no other cathartic than the scent of it. *Josephus Acosta* relates, that the air, along the ridge of the

* *M. Lemery* says, he was acquainted with by, in a most violent manner, both upwards and downwards. *Hist. de l'Academ. A. 1695.* two persons, who, staying four or five hours, in a hot season, where there was a large quantity of damask-roses, they were purged there-
p. 69.

Diseases from
Imagination.

high mountain *Pariacaca*, in *Peru*, has, for five hundred leagues, such strange effects, that, tho' he went well prepared to withstand it, yet, approaching the top, he was thrown into excessive retching and vomiting, even, 'till he cast up blood. It, likewise, 'operated, downwards, with some of his companions; and he continued, thus, sick for three or four hours, 'till he came into a more temperate air. A still greater proof of the power that effluvia have upon the body, arises from the propagation of infectious diseases. Nor is it a wonder, that such insensible particles should have such terrible effects upon our bodies, if we consider what alterations may, therein, be produced from the action of the parts upon one another. Several passions of the mind are often excited by the bare thoughts of absent things. In obstinate grief and melancholy, there is such an alteration made in the heart, and, perhaps, some other parts, thro' which the blood circulates, that the motion of that fluid is disturbed; and obstructions, and other disorders, occasion'd. The remembrance of a loathsome potion will, often produce a horror, attended with a sensible commotion of the whole body, and a kind of convulsion about the stomach. Shame, we see, occasions the blood to be plentifully thrown into the face; as will, also, great and sudden joy. I lately saw the latter passion do it, in persons of both sexes; when, not only their cheeks and fore-heads, but, even the neck and shoulders of the lady were left died of a red colour. Nay, passions, not only alter the motion of the fluids in the body; but, even, occasion the evacuation of some of them. Thus grief forces tears. And longing, in women, may well be supposed to create great alterations in the body of the mother, when it will leave such strange and lasting impressions upon that of the infant; since it is her, alone, that has such importunate desires.

There are many instances, in physic books, to shew, that imagination may cause a disease, where it is excessively fear'd; and I myself knew a lady who had the small-pox by this means. Nor is it, only, in women, that conceit has these effects. There was an *Irish* captain, in the county of *Cork*, of a middle age, who coming to surrender himself to my brother *Broghill*, at that time commander of the *English* forces there, was intercepted by a party of *English*. My brother being absent, the captain was so fearful of being put to death, before he return'd, that it soon alter'd the colour of his hair. Happening to be then at the castle, whereto this captain was brought, I found, upon examination, that the change of his hair was not uniform; but that particular tufts and locks thereof, with bases about an inch in diameter, were, up and down, suddenly turn'd white, all over, whilst the rest remain'd of its own reddish colour.

But I must not be understood to condemn the use of evacuating medicines, or be thought so credulous as to believe all the virtues ascribed, even by eminent writers, to specifics; for I have observ'd the best of these remedies to fail, where an emetic, or cathartic has not preceded; unless they were of so absterfivè a nature, as, of themselves, to free the first passages of those viscid humours that usually lodge therein, and hinder their efficacy. My design is to prevent the prejudice propagated by some learned, but confident physicians, who laugh at the mention of specifics, and allow no cures performable, without visibly evacuating the peccant matter; and, also, to shew, that such of these remedies, as men of judgment and credit recommend upon their own experience,

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are not, without trial, to be rejected, because they occasion no sensible evacuation, nor, manifestly, discover any eminent quality, nor, lastly, produce any remarkable change in an healthful body. For an animated human body is not a rude mass of limbs and liquors, but an engine consisting of several parts, harmoniously connected together, and communicating with each other; by means whereof, a weak impression of adventitious matter, in one part, shall act upon another, at a distance, or, even, upon the whole machine. The slight motion of a man's finger upon a small piece of iron, unconnected with any engine, would produce no considerable effect; but such an action, applied to the trigger of a loaded musket, occasions a surprizing succession of accidents. That a human body is so framed, as to suffer great changes from seemingly gentle impressions of external objects, appears from many instances already mention'd. Thus, likewise, to go, suddenly, into the sun-shine, will, sometimes, instantly occasion that violent motion we call sneezing. To look from a precipice, will make the head giddy; the sight of a whirl-pool has caused men to fall into it; and to fix the eyes upon the water, beneath a ship under sail, will prove emetic; as I, for my health's sake, have, sometimes, experienced. If a person be ticklish, stroke the sole of his foot with a feather, and it shall, against his will, affect the remote muscles of his face, and provoke him to laughter; as the tickling of a straw in the nostrils, excites sneezing. Many kinds of a grating noise will set the teeth on edge; and a servant of mine complain'd, that the whetting a knife would make his gums bleed. *Henricus ab Heer* mentions a lady who would faint at the sound of a bell, or any loud noise, even that of singing, and lye as if she were dead; but as she was thoroughly cured by a course of physic, it appears, that this disposition proceeded from some particular texture in her body, with regard to sounds. One hysterical woman, in fits, shall soon communicate them to another by aspect. And, to shew that distemper'd bodies may receive alterations, while sound ones remain the same; we need, only, consider, that the subtle effluvia, which float in the air, before any change of weather, are felt by those valetudinarians, who have, formerly receiv'd bruises, wounds, or other injuries; and that too, only, in the very parts where they happen'd. Others, we daily see, who are disorder'd by riding backwards in a coach; and the scent of musk, or amber-grease, tho' grateful to others, will throw hysterical women into strange convulsions. *Zacutus Lusitanus* tells us of a fisher-man, who, having spent his life at sea, and coming, accidentally, to the reception of the king of Portugal, in a maritime town, where perfumes were burnt; he was, thereby thrown into a fit, judged apoplectic by two physicians, who treated him accordingly; 'till three days after, the king's physician, guessing the cause, order'd him to be remov'd to the sea-side, and there to be cover'd with sea-weed, which soon recover'd him.

How much an alteration, produced in the body by sickness, may dispose it to receive impressions from what would not, otherwise, much affect it, may be guess'd from the effects of cold liquors thereon, when it is only heated: a man, in perfect health, who usually drinks his liquors cold, may, at that time, by a draught of cold water, or beer, be suddenly cast into such dangerous distem-

The Usefulness of Philosophy.

stempers, as, did not daily experience convince us, we shou'd think impossible to be, thereby, occasion'd, in a body free from morbid humours. *Benivenius* informs us of one, who, after vehement exercise, drinking a glass of very cold water, immediately, fell into a swoon and died: yet in bodies otherwise disposed, cold water has, sometimes, very good effects; and I know some hysterical ladies who find it an excellent remedy.

But the body is, also, as easily alterable for the better. The true moss of a human skull, tho' experience will not countenance all that the chymists say of it, proves sometimes a wonderful styptic. An eminent virtuoso, with whom I am well acquainted, as also his physician, assured me, he finds the effects of this moss so great upon himself, that his arm bleeding again, when tied up after phlebotomy, he took a little of it into his hand, and the blood immediately ceased to flow; he, thrice, for experiment's sake, laid aside the moss, when, his arm began to bleed again; but upon resuming thereof, it, each time, presently, stopp'd. The fume of burnt feathers, or tobacco, blown into the face of hysterical women, as suddenly relieves them from their fits, as perfumes occasion them. A friend of mine, a person of great veracity, professes, he has cured dysenteries, by fumi-gating the anus, and parts adjacent, with ginger, thrown upon hot embers, and receiv'd in a convenient posture, as long as possible, without too great faintness: but a master of chymical secrets prefers for this purpose harts-horn shavings. But if the heat, in this case, contributes to the effect, we may reasonably suppose, that cures are performable by particles more minute than those of smoke. And, indeed, I know a dextrous goldsmith, who, when he over-heats himself, is subject to the gripes; which he, usually, remedies by sitting, for some time, upon a heated anvil. Some find more relief in the colic from the smoke of tobacco reciev'd glyster-wise, than by any other physic; and, to my knowledge, some wealthy persons, relying hereon, never employ a physician for this distemper. And considering what a substance even common soot is, that many things, by being resolved into smoke, are more open'd than they wou'd be in the stomach; that, by this means, the operations of the many emetic and cathartic simples may be heighten'd; and that, probably, some fumes and odours are more powerful for not passing thro' the mouth; these things consider'd, I say, incline me to think some farther use might be made hereof. Not to mention, again, the great virtues of sulphureous smoke to preserve liquors; and that both *Paracelsus* and *Helmont*, highly extol, as a specific, the warts that grow on horses legs, against the fits of the mother; I lately met with a curious and intelligent person, who assured me, he was, by the scurvy and obstinate ulcers, brought exceeding low, and having, in vain, upon that account, undergone several tedious courses of physic, he resolved against them for the future; but lighting on a chirurgeon who had perform'd many extraordinary cures, by a method no way troublesome, he submitted thereto, and was soon cured. His method was to fumigate the patient very well, every morning, with a powder that appear'd of a vegetable substance. But as to the efficacy of fumes; I have, more than once, recover'd a young lady from strange fits, that we judg'd epileptic, by the scent of a little vial fill'd with rectified spirit of sal-armoniack, or harts-horn. And another lady, who, tho' she has long been subject to violent and lasting fits of the head-ach which was, greatly, increased

increased by a violent concussion, from the overturning of a coach; yet finds present relief by holding her head over a strong decoction of tea, and breathing the steams thereof. But there's one thing that seems, by no means, sufficiently attended to, in *Europe*; I mean, the constant and sudden ceasing of the plague, how violent soever, in that vastly populous city *Grand Cairo*, towards the latter end of *June*; when, in our hemisphere, it, usually, spreads the fastest. The truth of this is attested by travellers of different nations, as well as *Prosper Alpinus*, an excellent physician, who spent many years in that country, and gives this account of the matter. "The plague," says he, "begins in *Cairo*, and all the parts of *Egypt*, with *September*, and continues till *June*; in all the intermediate months 'tis communicated to them, by contagion, from abroad: but in the month of *June*, let the distemper there, rage ever so severely, as soon as ever the sun enters *Cancer*, it, perfectly, ceases; and what is very surprizing, all manner of goods that were infected thereby, become innocent thro' the whole nation, and every thing grows calm and well; only sporadic diseases, then, spring up, which nowhere appear while the plague rages. And this strange effect he wholly attributes to an alteration in the air. I desire this instance may be the more particularly consider'd, because it greatly confirms and illustrates what we have already said concerning the possibility of nature's curing diseases, without the help of gross and sensible evacuations.

We may farther observe, that the human body is alterable, both for the better and worse, by gross or mere mechanical motions. Persons are, often, recover'd from fits or swooning by bare pinching. I, who have gone thro' great and dangerous fits of sickness, scarce ever found any more violent, for the time, than that occasion'd by the motion and scent of a ship, together with the air at sea, before I was used to navigation; and yet this violent illness, as it was caused by no peccant humour in the body, was quickly removed by a quiet shore and change of air: and the like is, sometimes, observable upon riding in a coach; which is soon reliev'd by a cessation of the motion thereof. We see, in our stables, what effect the curry-comb has upon horses. *Helmont* says, he could tell, by the taste of the milk, whether the ass that gave it had been curried that day: but such an alteration seems to argue a greater in the blood and other principal parts of the body. *Piso* informs us, that the illiterate *Brazilian* empirics perform surprizing things both in the preservation of health, and the cure of many diseases, by their frictions in chronical, and unguents in acute cases. And as *Galen* commends a proper application of cupping-glasses in the colic; so in *Brazil* they find them very successful therein; being chiefly fixed, according to *Piso*, on the region of the liver. The horrid symptoms consequent upon the bite of a *Tarantula*, give way to nothing so well as music, which, by some means or other, causes the patient to leap, dance, and sweat, till he breathes out the virulent matter, that seems fitted for expulsion, thro' a change wrought either upon this, or the blood, by the music; for sudorifics and exercise, without music, are so far from effecting the cure, that, as *Kircher* informs us, the magistrates of *Apulia* allow public salaries for musicians, who play to the poor upon this occasion. The same author gives us a remarkable story of a nobleman, who languishing under a distemper, not suspected to proceed from the bite of a *Tarantula*, 'till he seem'd

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The Usefulness of Philosophy.

near the point of death, was, at length, suddenly reliev'd, and gradually recover'd, by music. And *Epiphanius Ferdinandus*, *Mathiolus*, and others, have the like relations. Now, that a sound may powerfully operate upon the blood and spirits, I my self, who delight in music, have often observed, upon hearing certain notes. This, also, seems probable, from the effect which, as we formerly said, a grating noise has upon the teeth and gums; and by the dancing fit in the present case, whereto it is only a particular tune that excites. Nay, *Kircher* farther affirms, that the *Tarantula* themselves, as well as the *Tarantati*, may be made to dance, by tunes suited to their constitutions. *Epiphanius Ferdinandus*, also, agrees herein, and tells us of a man ninety four years old, and render'd so weak, that he cou'd hardly walk with the help of a staff, who, being bitten by a *Tarantula*, immediately, at the sound of music, fell to dancing and capering like a kid. He adds, that not only men, in whom much may be attributed to fancy, but other animals do the same; and instances in a wasp, which he saw dance to music, together with the *Tarantula* that bit him; and also in a cock.

Peculiarities of constitutions.

But, moreover, there are many strange peculiarities in some persons, both in sickness and in health. These differences, indeed, between healthy men, may not be greater than that observable in the same person, between a sound and a distemper'd state; yet we, frequently, see, that some bodies are so framed, as to be strangely disorder'd by such things as either not at all, or else differently affect those of others. Thus, 'tis common for men to express great uneasiness, and fall into fits of trembling, at the sight of a cat. This was the case of the late gallant and noble Earl of *Barrymore*, who had the like aversion to tansey. And I my self cannot behold a spider near me, without a great commotion in my blood; tho' I never receiv'd any hurt from that creature, and have no abhorrence of toads, vipers, or other venomous animals. I also know an excellent lady, who is remarkable for a strange antipathy to honey. Her physician supposing this, in some measure, imaginary, mixed a little honey in a remedy he applied to a very slight scratch, she happen'd to receive on her foot; but he soon repented of his curiosity, for it caus'd a strange and unexpected disorder, which ceas'd upon the removal of that medicine, and the application of others. The same excellent person complain'd to me, that the vulgar pectoral remedies did her no service in coughs, wherewith she was troubled, and which nothing reliev'd but either the fume of amber, receiv'd by a pipe, with that of proper herbs, or, the balsam of sulphur. I know an ingenious gentlewoman, on whom cinnamon, which, generally, is, considerably astringent and stomachic, has a quite contrary effect, and this in a strange degree, so that having found by two or three accidental trials, that a very little cinnamon seem'd to disorder her stomach, and prove laxative; she, once, resolv'd to satisfy her self, whether these discomposures came by chance or no; and having strew'd some powder'd cinnamon upon a toast, she eat it, and was thereby purged, for two days together, with such violence, that it caus'd convulsions, and a spasmus, which she continues to be troubled with, from time to time, tho' 'tis three years since she made the experiment; as was averr'd to me by her husband, a physician*. A person of quality lately

* On the other hand, *M. Lemery* tells us, he knew a chymist, who cou'd eat *Mercurius dulcis* as if it were bread; and that he has seen him chew and swallow down four ounces at once, without any sensible effect. *Hist. de l'Academ.* A. 1699. p. 69.

asked me, whether he shou'd continue the use of coffee as an emetic; because he had found it operate very violently with him. Inquiring, particularly, into this odd effect, I found, that an ordinary wine-glass full of the common liquor, coffee, wou'd, in two hours time, vomit him more severely than the infusion of *Crocus metallorum*, or other usual emetics; that this had been, for several years, his constant vomit; that scarce any one was more irksome, than this, of late, grew, to take; so that the scent of a coffee-house wou'd make him sick; and, lastly, that he himself had formerly used it long together for the fumes which offended his head, without observing any emetic quality therein. The writings of sober physicians afford us many other strange instances of this peculiarity of constitutions; and of such as have desired to eat very extravagant and absurd things, which, tho' they, sometimes, were directly contrary to their distempers, have perform'd cures in desperate cases. And this appears the more probable from what we frequently see done by longing women, and virgins in the green-sickness. But now, if a human body be so framed, as to receive alterations from such unlikely things as these, why shou'd specifics be hastily condemn'd, which, tho' they operate insensibly, come recommended by the experience of sober and credible persons? That an inconsiderable quantity of matter, once admitted into the body, may give a new and unnatural determination to the motion of the blood, an alteration to the texture, either of that, or of some noble part, and as a little leaven, ferment the whole lump, appears from the effects of poisons, which are not produced by those the physicians call manifest qualities. Most writers upon poisons, indeed, supposing men wou'd rather believe than repeat their experiments, have deliver'd many things more strange than true; yet the known effects of a little opium, or arsenic, the scarce discernible virus emitted by the viper, and the small quantity of the saliva of a mad dog, less than half a grain whereof will destroy an ox, abundantly illustrate and confirm all we have deliver'd, upon the head of specifics. And that a morbid body may be, sometimes, cured with as small a matter as wou'd disorder a sound one, is manifest from that experiment, common in *Italy* and elsewhere, of curing the venomous bite of a scorpion, by anointing the tumid part with common oil, wherein live scorpions have been steep'd. *Piso* tells us, that he saw an huge over-grown toad, swell'd with poison, and desperately venomous, that was presently kill'd, by a *Brazilian*, only with dropping on his back, the juice of the plant *Nhanby*. He farther declares, that an infusion of the root *Jaborandi* rescu'd, to his knowledge, many from imminent death, who had eaten several sorts of poison; and this, after the whole tribe of *European* alexipharmics had proved unsuccessful. It may here be objected, that my instances only reach to poisons, and their antidotes, not to distempers, and their specifics. I answer, first, that physicians treat these as distempers, and that they, really, are so; but heighten'd by a virulent malignity, which is not easily distinguishable from them; as appears by the frequent disputes of physicians, whether or no their patients died of poison. Some of the *Brazilians*, indeed, according to *Piso*, are so dextrous in mixing their poisons, as to prevent the pernicious effects thereof, for a long time, after they are taken: but then, their quantity is so small, in comparison of the morbid matter of surfeits, or other similar diseases, their symptoms so dreadful, and consequences so destructive, that

The Usefulness of Philosophy.

the cure hereof best serves to shew how powerfully nature may be assisted by remedies, whose operation is insensible. Secondly, there are many passages in the preceding discourse, as, particularly, where mention is made of the cure of agues, the rickets, and the king's-evil, which shew, that common diseases, also, are curable by specifics.

New remedies to be used where the old ones have failed.

But suppose, say you, a recommended specific shou'd appear not only unable to cure, but likely to augment the disease? Why then, we must consider, 'tis better for the patient to be cured by rash and imprudent means, than be suffer'd to die according to art; and that the physician, who loses his patient, after having long struggled to save him, deserves more commendation than he who shou'd chance to cure one by an irrational method. The physician ought, therefore, to be well satisfied of the ground he goes on, before he ventures upon such a remedy, especially, if he has not tried the more ordinary and unsuspected means, and found them ineffectual; for 'tis not one lucky cure that will recommend a remedy to a wary physician, when the dangerous quality thereof seems obvious, and its virtues are only known by report. But then, if a physician be well assured of the efficacy of such a remedy, by a variety of trials, he may, surely, without rashness, make use of it, at least, where ordinary medicines have failed.

Many reasons might be produced to enforce this practice. And, first, the true nature and causes of several diseases, are more unknown to physicians, than is generally thought; nor is the particular method of cure, thereon depending, more settled among them. The generality of physicians, I fear, are guided by narrow scholastic principles, not by nature: nor have they, once, well enumerated and distinguish'd the several assignable causes for the phenomena of diseases; or told us, by how many different ways they, and their symptoms, may be removed. If this were analytically and carefully done, I doubt not but men's knowledge in physic, would be more extensive, and effectual, than it is at present; and we should, then, find many probable and promising methods of cure, which are now overlook'd. A physician, indeed, is, in a due sense, the servant of nature; yet, such kind of expressions, I suspect, has hinder'd the advancement of physic, by diverting the minds of men from thinking of those methods, which, by powerfully altering the human machine, rectifying the motion and texture of it's parts, and accustoming it to proper courses of the blood and juices, and time and methods of evacuation, might prevent, or cure some stubborn diseases, more happily than the vulgar means. And, 'till men have a better knowledge in the principles of natural philosophy, we must not expect a more perfect and comprehensive theory of physic. That the present practice often proceeds upon a false foundation, might be shewn in abundance of instances; but I shall mention, at present, only the last I met with. An intimate acquaintance of mine, having been many months troubled with a difficulty of breathing, was unsuccessfully treated for it, by some very eminent physicians; 'till, at length, suspecting 'twas not the lungs, but the nerves of the adjacent parts, that were affected, our volatile salt was given, which, quickly, relieved him, and he was, afterwards convinced, that the lungs were not in fault.

As the common method, in short, with the theories founded thereon, is, in many cases, so disputable, that the success of a remedy seems to be more probable

bable, than the receiv'd notion of some diseases; it were not amiss, if we consider'd the saying of the old empirics in *Celsus*. "We don't say, that a physician shou'd act, without reason; or, that an irrational creature can practise physic: but that conjectural hypotheses, about obscure things, belong not to it: for the question is not, what causes, but what cures, a distemper." And, as the proper method is not agreed upon, in the schools; so many, who are perfect strangers to them, by means of specifics, their own experience, and common sense, perform considerable cures. *Piso* gives the following testimony of the utterly unlearn'd *Brazilian* empirics. "The more elderly, and experienced, among them," says he, "are, excellently, skill'd in botany, and pharmacy; by which means, they easily prepare all kinds of remedies from what they find in the woods; and these they apply both externally, and internally, but especially in distempers occasion'd by poison, with so great sagacity, that it is safer falling into their hands, than into the hands of our raw physicians, who are, perpetually, boasting of their education, and secrets."

A physician, who practis'd, with great success, in *Dublin*, whilst new and violent fevers raged there, whereof multitudes died, and very few recover'd; happily hit upon a method that proved very prosperous; whereof he gave me the following account by letter: which may, perhaps, afford good hints towards the cure of some other ill-condition'd fevers.

Dublin, Feb. 27. 1682.

"I Have employ'd *Ens Veneris*, for the removal of a *Subsultus Tendinum*, in a person dangerously sick of a *Febris Petechialis*, (a disease fatal to very many, here, for these twelve or fourteen months;) and found that it answer'd my hopes, in three or four hours after I gave it, in conserve of borage flowers.

"I have thought of a method of curing the aforesaid fever, which has not once fail'd me; tho' I made use of it for sixteen or eighteen several persons; many of which, would, certainly, have died, if treated, after the usual manner, in this case. When first I come to any sick of this disease, if I find them costive, (as, generally, they are,) I prescribe a glyster, and, after that, a large blistering plaister, between the shoulders; the blister being well rais'd, and carefully dress'd, stripping off the cuticula, continues running till the fever is gone off; which happens, most commonly, in ten or twelve days, if they have not kept up too long with it; for then we cannot, certainly, foretel the time of the fever's declination. For the whole time, till the going off of the fever, I prescribe emulsions of *Aq. Aronis*, *Card. Bened.* *Citrj totius*, & *Syr. Granatorum*, cum *Aceto*; I allow of orange, and butter-milk possets, of roasted apples, flummery, or any other light, and cooling thing, they call for.

"By this method, I keep the *Genus Nervosum*, and brain, from being affected, and, consequently, secure my patients; for, as many as I have ever known of them die, in this disease, died of a disorder of those parts. I do not defer the blistering plaisters, till I find my patients delirious, lethargic, convulsive, or otherwise affected in their heads, and nerves; finding, by the experience of others, that, then, they, most commonly prove ineffectual, be-

“ cause of some morbid matter too deeply lodg’d in these parts. I do not pre-
 “ scribe, except upon some extraordinary occasions, any volatile salts, or spirits,
 “ or any thing too apt to quicken the circulation of the blood, which is already
 “ too great; having, experimentally, learn’d, that by these, often us’d, the brain,
 “ and nerves, become, sooner than ordinary, affected; for, they deeply infi-
 “ nuate themselves, and drive, with them, some morbid matter into the brain,
 “ and nerves. I find bleeding bad; being generally fatal. If I doubt of the re-
 “ covery of any of my patients, in this disease, ’tis, only, when I find they
 “ have been let blood, or lain for eight or nine days before I come to them;
 “ tho’ I have recover’d even persons in those circumstances.”

Medicines, appa-
 rently opposite to a
 disease, may cure
 it.

Secondly, there are many medicines endow’d with a quality, apt to encrease the disease wherein they are prescribed, whose use is yet approved of by the most judicious physicians, because they possess others which produce superior good effects. Thus, in a malignant fever, *Venice-treacle*, and other hot sudorifics, are order’d, since they relieve the patient more, by some other means, than an encrease of heat, for a season, can prejudice him. *Bontius*, for the spasms, which he reckons endemial in the *East-Indies*, commends the use of *Quercetan’s Laudanum*, of *Philonium*, and, particularly, of an extract of opium, and saffron; and, to prevent any prejudice against the use hereof, he adds, that, “ an unexperienced practitioner might, here, refuse to prescribe these medicines, because of the supposed benumbing quality of the opium; but the excessive heat of the climate,” says he, “ requires it; and, besides, we find it the only cure, in this case. But, opium, in these parts, is so prepared, that it may, safely, be given to infants; and, then, ’tis so useful, that, tho’ it may seem surprizing, we can do nothing in hot diseases without it.” The use of cold water is, commonly, forbid in a dropsy; yet the *Spaw* is famed for curing that distemper. And, I know a person of great quality, who, in a case complicated with this, in a great degree, being thought incurable by her physician, surprizingly recover’d upon drinking the waters of *Tunbridge*. So hot a wood as guaiacum, is, I believe, generally thought a dangerous medicine in a phthisis; yet some eminent physicians, and, particularly the *Spanish*, relate wonderful cures, perform’d by the continued use of a decoction thereof, in desperate ulcers of the lungs. And a very learned physician of my acquaintance, confirms this to me, from his own experience, in consumptions. Mercury is thought prejudicial to the nerves, and brain; yet, one of the happiest physicians I know, owns, that he, very successfully, uses preparations thereof in the palsy, and similar cases. And, I remember a gentlewoman, confin’d to her bed, with the palsy on one side, upon taking a dose of a mercurial preparation, corrected with gold, which I gave her eminent physician, for that purpose, tho’ it only purged her gently, was enabled, the day following, to walk about the room.

Thirdly, many things that seem, when first proposed, to be contrary to reason, are, afterwards, found very consistent therewith. There are some substances, which, tho’ they appear similar, or homogeneous, are endow’d with different, or contrary, qualities; as we see, not only from a chymical analysis of bodies; but, also, where no fire is applied. Thus, *rhubarb*, being taken in substance,

stance, the subtile part thereof proves purgative, and the terrestrial astringent. Nay, if the parts, which have the least share in the constitution of the whole concrete, happen to meet with a body disposed to receive their impressions; 'tis very possible, they may operate more strongly thereon, than those whereof the eye judges it altogether to consist. And this I have made appear, by shewing, that sallet-oil, which is thought to consist of fat, and unctuous particles, contains, also, some that are sharp and corrosive, which, happening on a proper subject, operate more powerfully than the former. For, keeping some pure olive-oil, a small time, upon filings of crude copper, in a gentle heat, the liquor extracted a high tincture, between green and blue; which, therefore, dissolved some part of the copper; as farther appears, from the recoverableness of the metal out of it. But to proceed; an ingenious chymist, whom I advised to bleed for a pleurisy, which he refused to do, cured himself, only by *Helmont's* laudanum, in two or three days: and by this means, he, also, since that time, cured some others, without phlebotomy. I am the less surpriz'd hereat, because I have found, that, opium, duly corrected, is a great resolver, and, sometimes, proves sudorific: nay, I, once, knew it do so, when other medicines, of that intention, fail'd. I have known coughs strangely abated by a very saline medicine; wherewith, I, in a few hours, reliev'd a child, who, by the violence of one, seem threaten'd with speedy death; and, yet, many physicians condemn all salt things, in this case. And, from the vehemently pungent spirit of human blood, I have known, notwithstanding its very saline, and heating quality, strange effects, even in a deplorable, and hereditary consumption. But, what seems more surprizing, a very ancient *Galenist*, esteem'd as an oracle, especially in pulmonic consumptions, which were common in his country, having used various means to cure them, both in himself and others, confessed, he found nothing so effectual as sulphur melted, and mix'd with amber, and a cephalic plant, as betony, to allay the pungency of the sulphur, and so smoked like tobacco. The sulphur, however, was so predominant, that he kept a syrup in readiness, to heal the soreness it might occasion in the mouth. And, with the same remedy, a very curious person solemnly assured me, he had cured many consumptions, particularly once in a lady, whom, even in health, I knew to be very lean. Now, physicians, generally, forbid the use of acids, when the lungs are ulcerated, or tender; and, yet, the fume of sulphur is what condenses into that highly corrosive liquor, called *Oleum sulphuris per campanam*, which will, readily, dissolve iron. From hence it appears, either, that the theory of consumptions is misunderstood; or, that the balsamic quality of the sulphureous steam, is great enough to prevent the ill effects of its acidity. The dried livers, and galls, of eels, which are, usually, remarked for nothing but their crudity, have, if we credit *Helmont*, prevented multitudes of women from dying of a hard labour. *Panarola*, also, commends them for the same purpose; and, I knew a famous empiric, who got much reputation, and money, by selling this as a secret. I my self, also, gave it to the wife of an ingenious physician, when he, and the midwives, had almost despair'd of her; and, as she, afterwards, told me, each dose made her throws, which before had left her, return; and that, at length, she was deliver'd, she scarce knew how. But, I, here, found the quantity of a walnut of the powder, which is double to that

The Usefulness of Philosophy.

of *Helmont*, necessary for a dose, in rhenish, or white-wine, upon an empty stomach.

Did not experience assure us of the contrary, one wou'd think, that, to suffocate scorpions in oil, shou'd make it venomous; which, yet, is the cure of their poison: an effect, now the physicians find it true, they pretend to account for. The flux is endemial in *Ireland*; but, consulting an ancient and experienced physician, there, concerning it's cure; he assured me, he found nothing more effectual, than fresh butter, melted, purified, and given in a large quantity; which seems more apt to cause, than cure, that distemper. And another ancient physician, there, afterwards, greatly commended it to me, in the same case.

*Specifics, how
they may operate.*

I shou'd no longer insist upon the recommendation of specifics, did I not find, at every turn, that learned men, and, especially, a famous foreign university, reject them, for not knowing the manner of their operation; believing it absolutely improbable, that a medicine which must pass thro' several digestions, and circulate with the blood, shou'd neglect some, and befriend other parts of the body. To this objection I wou'd offer two things. And, first, I demand of these gentlemen, an intelligible explanation of the manner wherein the common medicaments operate; as how rhubarb purges choler, and hellebore melancholy, rather than other humours; how *Antimonium diaphoreticum*, and *Bezoarticum minerale*, after having long endured the fire, come to be sudorific; how the infusions of *Crocus metallorum*, and glass of antimony, tho' they have no manifest power to vellicate the tongue or palat, are both, violently emetic and cathartic; and, lastly, how mercury, which, in many cases, is given, with safety, to women in labour, &c. besides having many other abstruse, medicinal qualities, becomes not only emetic and cathartic, but also salivates? For I must confess, that many of the vulgar operations of common drugs seem not to me, satisfactorily explain'd by physicians, who even are at a loss, in accounting for the effects of diuretics, sudorifics, narcotics, and many other familiar medicines, which, those who consider them only superficially, think they understand. Nay, I greatly question, whether the generality of physicians can, yet, give a satisfactory reason why any sort of medicine purges in general. But he who will shew me where either the *Galenists* or *Peripatetics* have, clearly, made out why rhubarb purges choler, and sena phlegm, *erit mihi magnus Apollo*; for I cannot conceive how their narrow and barren principles shou'd do it. And the only reason, that I can find, why physicians, who are ignorant of mechanical philosophy, think they know such things, is, because they never, attentively, enquired about them. Secondly, a due application of mechanical philosophy will, perhaps, more easily shew, at least in general, that specifics may produce the effects which judicious and experienced men have ascribed thereto, than the vulgar principles can account for the most obvious and easy operations of medicines. And tho' the objection urged to prove, that specifics cannot affect only particular parts, lies equally strong against poisons proving noxious to particular parts; yet experience demonstrates that these, actually, prove hurtful to some parts, without equally, if at all, offending others. Thus cantharides affect the kidneys and bladder; quick-silver, the glands in the throat; *Stramonium*, the brain; and opium, the nerves and animal spirits.

Now if the body, as we have made it appear, is a machine, and medicines operate upon it accordingly; 'tis not strange there shou'd be therein several strain-

ers.

ers of different textures, with, perhaps, local ferments in particular parts; and, the mass of blood, continually flowing thro' the whole, that a medicine shou'd be convey'd, from one part to another, by means thereof, and, at length, arrive to the parts or humours which their textures, the ferment abovemention'd, or some other mechanical properties, fit and dispose to be operated upon, thereby. Saline and tartareous aliment, whilst circulating in the mass of blood, may, thereby, be diluted, and kept asunder, so as not to offend any part, till it comes to be secreted in the kidneys, when, by its pungency, it may wound the ureters and tender bladders of those afflicted with the stone: and upon this account, perhaps, cantharides only affect the bladder. Thus, also, a specific may be disposed to dissolve in the body, and either preserve or acquire a proper disposition for the pores of the kidneys, liver, or other strainer; or its particles may be endow'd with a figure and motion fit for adhering to those of the peccant matter, (which, thro' their vehement agitation, or other offensive qualities, disorder the body,) and, by altering their bulk and shape, give them new and innocent properties. Another specific may dissolve the gross and slimy matter obstructing the veins; as I have observ'd, that spirit of harts-horn, which powerfully opens obstructions, and resolves viscid phlegm, in the lungs, will, also, dissolve, tho' more slowly, flowers of sulphur, crude copper, &c. It may, also, obtund the acid spirit that causes coagulations in the blood, and restoring this to its fluidity and circulation, prevent formidable diseases that arise from it, when sily. On the contrary, the minute parts of some specifics may thicken and fix the too thin and fluid parts of the blood, or peccant matter, by associating themselves therewith; as the agile parts of pure spirit of wine will coagulate with those of rectified spirit of urine, and also with another liquor I make, into a kind of soft, but solid substance. Nor is it hard to conceive, that a specific shou'd work upon one part of the body, and not upon another. We have, already, instanced in vinegar, which dissolves the shell, and leaves the skin of an egg, untouch'd; and if coral be thrown into common rectified spirit of tartar, the greater part of that fluid will remain unalter'd; but acid particles will, immediately, incorporate therewith, and thereby lose their acidity: and this effect, coral has been observed to produce in human bodies, the acid humours being, perhaps, brought, by the blood, into the stomach and guts, whilst that remain'd therein. But, in other cases, the operations of remedies may be more sudden, by diffusing themselves, at once, thro' the mass of blood, and associating with, and destroying, the acid particles. Thus, spirit of urine, put to that of tartar, only coagulates with, and affects, the acid therein contain'd; whilst the spirituous, and phlegmatic parts remain as they were. And, surely, if some cathartics purge electively, as our opponents assert, and some antidotes are adapted to some poisons, as experience manifests; specifics may be allow'd, to act after the same peculiar manner.

More examples, of the efficacy of specifics, might be here produced, but these may suffice at present; especially, if we consider, that as physic owes its origin to experience, so those who practise it, must enlarge and rectify their principles by the new discoveries that are made, either in art or nature. The old empirics, as we find them speak in that excellent preface of *Celsus*, fully express my sentiments on this head. "Thus," say they, "physic gain'd ground, by observing, from the recovery

Physic still improves by experience.

The Usefulness of Philosophy.

“ of some, and the death of others, what was salutary, and what was noxious; “ and, after remedies were found, men began to argue about them; for phyfic “ was not the invention of reason.” And to this purpose *Aristotle* excellently says, “ where the fact is plain, tho’ it appear improbable, we shou’d not reject “ it; but enquire into the cause thereof.” ’Tis true, credulity is of very pernicious consequence in a physician; yet the world is little obliged to those who, rigidly, confine the operations of nature to their own narrow limits; without allowing, either themselves, or others, to try, whether such things are performable, as they never saw done, and their common school-principles cannot account for. ’Twould have seem’d incredible, a few years ago, to those who were only acquainted with vegetable cathartics and emetics, that a cup, made of a substance, insoluble by the stomach, shou’d, without any sensible diminution of its weight, communicate a strong cathartic, and emetic, quality to any liquor pour’d therein; and, notwithstanding, discover no alteration, either in its colour, scent, or taste; yet, a slight preparation of antimony, with salt-peter, or, singly melted into glass, will do this. And thus, also, which seems more surprizing, the common *Crocus metallorum* is said, in a small quantity, to render wine as strongly emetic, as if a greater had been therein infused. That a fixed stone, capable of sustaining the heat of a reverberatory fire, being taken in the quantity of about half a dram, and continued for some days, shou’d consolidate broken bones, might seem impossible, were it not well known, that the *Lapis ossifragus*, or, rather, *Osteocolle*, as ’tis deservedly call’d, has this property. *Quercetan* relates such wonderful cures done by it, used both internally, and externally, in fractures, without the usual symptoms, and in four or five days time, that, he tells us, it might seem incredible, had not other proper persons beheld the same, as well as himself: and well might he say thus, since, as chirurgéons observe, nature is, usually, forty days in forming a callus in the bones. *Matthiolus*, *Fabricius Hildanus*, and *Sennertus*, also, confirm this great virtue of the same medicament; and the latter tells us, that, “ in youth, and a good habit, it causes the callus to grow “ too fast, for which reason, says he, it shou’d, only, be used in grown persons, “ and not too freely.” And, that this caution is just, I was, lately, convinced, by a learned physician, who had studied the nature of the stone, and told me, that his mother, having formerly broke her leg, suddenly occasion’d an exorbitant callus, by taking too much of it. He, who, before the salivating property of mercury was discover’d, should have told such physicians as our opponents, that, besides the usual ways of evacuation, there was a sort of remedy, which, operating by the salival glands, cured distempers, that were incurable by ordinary means, wou’d, I question not, have been laugh’d at; yet this property is, now, indisputable, and has proved so successful, in venereal distempers, that I wonder those who scruple not to use rough methods of cure, have not, yet, applied it in ulcers of the kidneys, consumptions, palsies, &c. * wherein, I am inclin’d to

* This has, of late, been, abundantly, perform’d in *France*, where they freely use the mercurial frictions in such cases, and with great success. But an exact history of the cures, perform’d by mercury, applied in this manner, having never been publish’d, the *English* are more

shy of it than, perhaps, they otherwise wou’d be. However, we can produce instances, among our selves, of very stubborn and radicated cases, which have given way to mercurial unctions, when other remedies had failed.

think,

think; it might prove as effectual; especially, if the tormenting symptoms of the salivation, which are scarce supportable, could be prevented. And, if mercury be dextrously precipitated, by a long and competent digestion, with a due proportion of refin'd gold, experience has inform'd me, that it salivates with much more ease to the patient, than the common mercurial preparations*. Besides, I am inclin'd to believe, from trials, which I have procur'd experienced physicians to make, both in venereal, and other, distempers, that medicines, wherein the quick-silver is well corrected by gold, may have extraordinary effects. I cannot, here, omit an uncommon cure, perform'd with mercury, related to me, by the chymist to the king of *France*. A person of quality, *Monseigneur de Vatteville*, who commanded a *French* regiment of *Swiss*, had a violent distemper in his eyes, which, notwithstanding the utmost endeavours, both of physicians and surgeons, grew, in a few months, to a total blindness; in this state he continued for many years, 'till hearing of a famous emperic, *Adrian Glassmaker*, who perform'd strange cures, with a certain powder; the colonel went to him, and, resolving to undergo the torment of his method, the emperic undertook him, and order'd about a grain of his mercurial powder, a kind of turbith, made by precipitating quick-silver with oil of vitriol, &c. to be snuffed up each nostril, which, immediately, operated in a violent manner, by vomit, stool, sweat, urine, salivation, and the lachrymal glands, for twelve hours together; causing, also, his head to swell greatly; but within three or four days after this single dose had done working, the patient began to recover his sight; and, in a fortnight's time, saw better than ever, or, than men usually do. The colonel purchased the receipt of the powder, and presented it to *Monf. Benoist*, a surgeon, who cured him of a broken thigh, when others were proceeding to amputation; and he, by using it, in the same manner, cured a gentlewoman of a cancer in her breast.

It will appear strange to some persons, that, in this whole discourse, I have not once touch'd upon universal remedies: the reason is, I am not well satisfied about their possibility. Yet, methinks, we confine our thoughts too much, if we don't expect, that a generous medicine should cure more than one kind of disease. The theory of distempers is not, yet, so accurate and certain, that we should neglect the manifest, or promising virtues of noble remedies, where we cannot reconcile them thereto. A translocation of the morbid matter, from one part to another, frequently occasions different disorders. Thus I have observ'd the cause of a cough, removed from the lungs to the brain, has produced a sudden decay of memory, and the reasoning faculty, together with a partial palsy. It seems probable, therefore, that a medicine, endow'd with proper qualities, may operate upon the morbid matter, wherever it can meet therewith; and so effect a cure. It, also, frequently happens, that diseases, to appearance, of a

* To obtain the full virtue of mercury, without raising a salivation, were a very desirable thing. This is attempted by some physicians, and, particularly, by those of *Montpellier*, in the way of frictions, which they apply, at such distances of time, as to prevent the rise of a

flux at the mouth. The chancellor of that university, *M. Chicheynau*, has publish'd a thesis upon the subject; wherein he, earnestly, recommends the practice, and produces some instances of its good effects, from his own experience.

The Usefulness of Philosophy.

quite contrary nature, proceed from the same cause, differently circumstanced ; or that various diseases, which seem original, are only symptomatic. Thus a dropsy, and a slow fever, seem opposites ; yet an expert physician knows they may, both, proceed from the same cause, and have the same cure. An ignorant physician would think the numerous symptoms in hysterical women, original distempers ; and they have, often been, unsuccessfully, treated accordingly ; when uterine medicines would allay them, all at once. I lately knew a practitioner, who used the same volatile salt in dropries, and original fevers ; and a preparation of hart's horn, not much unlike it, has, by me, been found equally serviceable in primary coughs and fevers. And we have, already, enumerated various remedies, which prove effectual against diseases, judg'd, from the common theory, to be opposites ; not here to mention my own observations on *Helmont's Laudanum*, my *Ens Veneris*, and the lady *Kent's* powder. Many distempers that appear of contrary natures, are, if we may credit *Henricus ab Heer*, yearly cur'd by the *Spaw*-water ; and of these he gives us a long detail. But after having expressly asserted these waters to have the virtues, both of hot and cold minerals, and that the same, as well as different patients, are, accordingly, cured, both of cold and hot diseases ; he gives an instance to confirm it. " These waters," says he, " among their other good effects, are excellent to bring down the menses, as I have, a thousand times, experienced ; and, yet, they restrain them, when violent, better than any medicine whatsoever". And I, lately saw, at *Tunbridge*, something that seems to countenance what this experienced author delivers of the *Spaw*. Thus, then, we see, one potent remedy may cure several, supposed, contrary diseases. And it deserves to be farther observ'd, that when the receiv'd practice fails, the tired and despondent physician sends his patient to the wells, in hopes that a remedy, prepared by nature, may do more than those prepared by art. This observation, being well consider'd, together with the possibility there is that art may meliorate and improve most remedies, afforded by nature, one might dare to hope, that medicines of greater efficacy, may be prepared, and applied to more cases, than those who admire the common, arbitrary theory of diseases, and judge of remedies by what is sold in apothecaries-shops, expect. My design, however, is not to subvert those principles of the *methodus medendi*, wherein all physicians, unanimously, agree ; much less would I countenance those bold empirics, who, without a competent knowledge in anatomy, botany, and the history of diseases, think receipts, alone, can enable them to cure diseases which they don't understand. No, through the whole of this discourse, without, peremptorily asserting any thing, I have barely represented my notions, as deserving an impartial consideration ; so that, in case they are rejected, it may not be, before the things have had a fair trial and examination ; but that, if they happen to be approved, they may serve as instances of the usefulness of natural philosophy to physic : and if any thing I have said, may conduce to that end, I shall think my time well spent in this study. Man is so noble a creature, and his health so requisite to his well being, and the discharge of his several duties, that I wonder not the heathens ascribed the art of healing to the gods, and advanced it's happy professors among them. The principal end, for which I study chymistry, is to relieve some languishing patients the more easily
from

from their sickness; for, certainly, our common remedies are very ineffectual; not to mention the fatigue they occasion in taking. We daily meet with too many, who, like the woman in the gospel, have "suffer'd many things of many physicians," and spent their whole substance upon them, without being ever the better, but rather worse; for which reason, I esteem the inventing and divulging useful things in physic, and the recommending of good remedies, among the most extensive acts of charity, whereby a man becomes, really, more serviceable to the world, than by building an hospital. What numbers have owed their health to mercury; and, consequently, how many more persons are obliged to *Carpus*, or whoever discover'd it's use, than have recover'd in the largest hospital, in the world?

I am sensible, indeed, 'tis reputed more fashionable, in young gentlemen, to get into the army, and to kill their fellow creatures, than to cure them; and that 'tis thought a fine exercise to destroy the noblest workmanship of nature; but the character of our great master was "that he went about doing good, healing all manner of sickness, and all manner of diseases among the people"; which is an employment worthy even the noblest of his disciples.

PART III.

Shewing the advantages of natural philosophy to human life.

SECT. I.

I COME now to shew, how natural philosophy contributes to afford us the necessaries and conveniencies of life; whereby our empire is extended abroad, as a knowledge in physic, secures us at home. And, methinks, it appears highly probable, that good naturalists may, greatly reform trade, or improve it; since, in general, it depends, only, upon a small number of particular productions of nature; and, chiefly, lies in the hands of the illiterate. Thus, for instance, the husbandman's skill consists in the knowledge of a few plants and animals, their relation to particular soils, and management, with the influence of the celestial bodies and meteors thereon; all which subjects fall, properly, under the cognizance of a naturalist. He, therefore, who has attentively consider'd the nature of generation, nutrition, and accretion, both in plants and animals, and knows how to vary an useful experiment, so as to remedy the inconveniencies, or supply the defects thereof, and can, dextrously, apply his own, and others observations, may cultivate husbandry to as much advantage as the ordinary farmer tills his land. An attentive consideration of the parts that constitute

*Natural philosophy
tends to reform,
and improve trade.*

stitute each particular trade, would shew how they all depend upon philosophy, and might be farther improved. Thus, the principal parts of refining, are a knowledge of the preparation of *Aqua fortis*, and its operation upon silver, copper, and gold, with the means to purge it, that, neither gold may be dissolv'd, nor silver precipitated, when dissolv'd thereby; to know what proportion is dissolvable therein, and the quantity of water, necessary to weaken the solution; how long copper-plates should lye to precipitate the silver it contains; how lead is colligated with, and what proportion thereof is requisite to carry off, the baser metals upon the test; how cupels are made, and, with these, to draw off lead, or antimony, from silver, or gold; to discern when the metal is, sufficiently, refin'd; and, lastly, to know the proper proportion of gold, and silver, to make water-gold*. This trade, indeed, is understood by few, and not so diffusive and complicated as hundreds of others; yet, if they all were judiciously resolv'd into their component parts, it would, doubtless, appear, that most of them are, only, corollaries, deduced from particular observations in philosophy, or the bare application thereof, to the uses of human life. And, if so, 'tis very probable, that farther discoveries in the nature of the materials, the subjects of trade, and a knowledge of the laws they observe, may reform, or meliorate, several of it's branches. This, too, is performable by odd and unsuspected means; so that, perhaps, the chymist's char-coal, may prove an excellent equivalent for manure; if a vegetable salt, as probably it is, be the cause of the land's fertility. For, chymical experiments may discover the nature hereof, and, thereby, afford useful directions towards the melioration of arable, pasture, and wood-land. From the experiments I, myself, have made upon earths, dungs, and seeds, whereby, I found, that salts abounded in the liquors they yielded; I see reason to wish this inquiry were farther prosecuted, towards the improvement of husbandry. Whoever has observ'd those many particulars in this art, which caused Sir *Francis Bacon* to pronounce nitre to be the life of vegetables; and, considers; how land is improved by pigeon's dung, which impregnates it with salt-petre; and, lastly, knows, that most fat earths, defended from the sun and rain, and left to themselves, will, soon, abound in nitrous salt; whoever, I say, considers these things, will, perhaps, believe an inquiry into the nature of salt-petre, may be of great use in farming.

Land improveable
by means of chymistry,
hydrostatics, &c.

I, once, caused some earth to be dug up, from under a pigeon-house, and distilling it, in a retort, little, or no oil, but a considerable quantity of a reddish liquor came over; so far unlike spirit of nitre, that it greatly resembled volatile salts; for, without being rectified, it not only turn'd syrup of violets green, and precipitated a solution of sublimate, into a milky substance; but there, also, came over, therewith, into the lower part of the receiver, a dry salt, in taste like the volatile kind, and so far an alkali, that it readily hissed, and caused an ebullition in an acid menstruum. From hence, it seems, which is high-

* For a particular account of this art, see *Philosophical Transactions*, No. 138. p. 955. and 142. p. 1046.

ly remarkable, that a salt, very different from acid, may, by the operation of the earth and air, be so alter'd as, afterwards, by a slight management, to afford salt-petre, whose spirit is strongly acid. And dropping *Aqua fortis* upon pot-ashes, dissolv'd in a little fair water, 'till the ebullition and hissing were perfectly ceased; and, having filter'd this liquor, and set it in an open vessel to evaporate, with a gentle heat; being, in two or three days time, removed to a cold place, it afforded very pure crystals of salt-petre.

I might add, that the knowledge of the nature, and distinctions of saline bodies, may, greatly, assist, to shew the differences of the various saltness that is found in soils; and with what sort each plant, or seed, is most delighted. By this means, many tracts of land, now thought barren, for want of a knowledge hereof, might be render'd useful. And ground may be made to yield much better crops, than usual, by being, successively, sown with a proper variety of seed, agreeable to the nature of the particular salt, at present, inherent in the earth; for, by the absence of one kind of salt, it is better prepared to feed those plants that delight in another. And of this, the husbandmen have, in some measure, already taken notice; as appears by their sowing turneps, in grounds too remote for the convenient carriage of compost, to serve for manure, and fit them for wheat. And, I am of opinion, than any land, except mere sand, might, without much culture, be made fertile, were we but well acquainted with the soil, and provided of the various sorts of grain, that nature affords, in different countries. There are various soils, both in *England*, and elsewhere, left quite uncultivated, wherein some foreign vegetables might thrive and prosper. Many large tracts of steep and craggy land, exposed to the southern sun, lye waste, in several hot countries, where grapes are not planted; tho' in *France*, *Italy*, and, even on the *Alps*, such lands are turn'd into excellent vineyards. An experienced way of causing wheat to grow, and prosper, even in clay, where no grain had thriven, was communicated to me by a person who had used it: and the art consisted in steeping the seed, for a determin'd time, in a certain express'd oil that is not dear; whence, 'tis probable, that, without altering the soil, a slight change, properly made in the seed, alone, may so fit them, for each other, as to yield a large increase. I have, also, seen, in a collection of rarities, an ear, or two, of corn, not much unlike our common wheat, one grain whereof, in a warm country, from whence this was brought, would afford so vast an increase, that the possessor was, almost, ashamed to declare; and, I am more afraid to repeat it. An *English* gentleman, however, assur'd me, that having sown some of this corn, in land of his own, he found a single grain to produce several hundreds; tho' that came nothing near what it was said to do, in a more suitable soil and climate. The learned *Acosta* affirms, that, in several parts of *America*, where the *European* wheat will not prosper, the *Indian*, or *Virginian* sort, call'd, also, *Maize*, succeeds so well, that tho' the grain be large, and more than one cluster often found upon one stalk; yet, in a single cluster, he has counted seven hundred grains. He adds, 'tis not unusual, in that country, to reap three hundred times the quantity sown. This, indeed, seems, a little incredible; but I, myself, have found, even in *England*, such a multitude of grains, in one of the

The Usefulness of Philosophy.

vast number of ears, produced from a single grain, that I am inclin'd to absolve *Acofta*.*

In some *Eastern* countries, a sort of rice, the chief food of the natives, thrives, excellently, upon land so watery, that the person is there obliged to wade, who sows it. Yet, this is less strange than what *Martinus* tells us, as a practice in some parts of *China*; where many places, that lye, all the year, under water, have seed so well appropriated to them, that, tho' thrown in the water, as baits for fish, it shoots up in it's proper season, appears on the surface, like a verdant field, and affords a plentiful crop.

To proceed. Chymistry and hydrostatics may help to discover the kinds and degrees of saltness, residing in several other bodies, the husbandman employs. I, myself, have made surprizing discoveries, in working upon some sorts of earth, by chymistry. And, as in particular, the fertility of manure, seems to depend upon it's salino-sulphureous parts; a practical inquiry into the differences and various operations of salts, may, probably, assist to discover various kinds of compost, with the proper manner, wherein to multiply, compound, and apply them.

And, thus, not, only, fire, but water, by means of the engines, and contrivances to be learnt from hydrostatics, may be made more serviceable to husbandry than ordinary. *Martinus* assures us, that, in one province of *China*, they water their rice-fields, by means of moveable mills, placed, as occasion requires, upon any part of the banks of a river. The wheels, here, raise the water, in buckets, to a great height, above the surface of the river; whence 'tis, afterwards, convey'd to the destin'd places, in proper channels. But, the art of levelling, or conducting water upon the ground, may be, farther, serviceable in this case. For soils, suited to this way of culture, are, thereby, greatly improveable; tho' it be, almost entirely, neglected, both in *England*, and elsewhere. Some ground of mine, by being skilfully overflow'd, has doubled it's increase. And I have, also, seen a wild boggyish place, turn'd, by a person of quality, into a good dry and compact soil, by, barely, trenching and overflowing it equally, six or seven times in a year, between the beginning of *October*, and the middle of *April*, with water from a neighbouring spring, that is enrich'd by no land-floods, and rose in a barren and uncultivated place; so that this ground afforded hay, in such plenty, as to become worth twenty times it's former purchase. Other instances, of the like improvement, I have met with, from, skilfully, overflowing grounds with common water.

I must here observe, that the more comprehensive any trade is, the more improvements it will admit of from philosophy; because, depending upon many natural productions and operations, there must arise many particulars to be meliorated, or reform'd, either in the manufacture, or profession. Thus corn, in husbandry, renders a knowledge of the whole art of tillage convenient, with the ways to order cattle, the dairy, an orchard, a kitching-garden, wood, flax, hemp, hops, bees, &c. and the particular productions of some of these, as honey, cyder,

* For the improvement of agriculture, see *Philosophical Transactions*, N^o. 116. p. 359. N^o. 225. p. 412. N^o. 237. p. 44.

&c. are capable of improvement, and require skill to manage. In the variety of particulars, therefore, wherewith the husbandman deals, there must be some, wherein the superior knowledge and experience of the naturalist, will be serviceable. And, as one of the principal parts of husbandry depends upon preserving cattle from diseases, and the fruits of the earth, from putrefaction; natural philosophy may conduce to both these ends. He who can accelerate, and delay putrefaction in bodies, may shew the husbandman how to prepare variety of manures; to enrich his ground with the peculiar kind of salt it wants; and, also, how to preserve several seeds, flowers, and fruits, beyond their natural duration. Thus many, by my recommendation, have continued fruits, as quinces, for instance, good, almost, all the year round, by a pickle made, only, of water, and the refuse of quinces, or what is easily obtain'd from them: but cherries I have preserved fresh and juicy for more than a year: and that without salt, or sugar, only by a proper spirit of wine, well impregnated with the tincture it drew from the skins of the same kind of fruit.

The great advantage accruing to the *Dutch*, from the best way of pickling herrings, and to others, from so ordering the flesh of animals, as to keep sweet, in passing from *Europe* to the *East-Indies*, and, sometimes, even 'till it comes back again from thence, may shew what benefit husbandry might receive from discovering means to preserve the productions of the earth; but, especially, if it could be extended to small wines, cyder, perry, &c. that are, commonly, made in large quantities; but soon decay, at home, and are unfit to be transported to very distant countries. The virtue of sugar, to strengthen vinous liquors, and render them durable; and the method of preserving great variety of fruits, and the juices of plants, without the help of salt, or any thing sharp, give some reason to expect, that very different ways may be found to make substances out-last their natural term of duration.*

Again, that great damage the husbandman, often, sustains by stubborn and contagious diseases in his cattle, might, in good measure, be prevented by the instructions of the naturalist, especially if skill'd in phyfic. For, as many diseases, so, many cures, also, are analogous in men and brutes; tho' remedies, for several reasons, usually, succeed best in the latter. A gentleman, of my acquaintance, has, for several years, preserved his numerous flocks, in a moist country, when most of his neighbours lost theirs, by the use of *Spanish* salt. After having bled them, a little, under the eye, he obliged them to take down, a small handful of it, two or three times in a few days; without permitting them to drink any thing, for some hours, after it. This remedy he employ'd, at that season, when there is a suspicion the sheep will begin to be bloch'd. I might here alledge, the virtue of crude antimony against the foulness of the blood, and leprosy in swine; of quick-silver, against the worms in horses; of

Husbandry by medicine, in curing the diseases of cattle.

* To preserve fruit and flowers for a whole year, take salt-petre, one pound, bole armeniac, two pounds, common clean sand, three pounds; mix them together, and, in dry weather, take fruit, or flowers, of any sort, not fully ripe, each with its stalk, and put them singly, into an open glass, 'till it be full; cover

it close with oil-cloth, and, in a dry cellar, put each of these glasses four fingers deep, under ground, so, that quite round, above, as well as below, there may remain two fingers thick of the mixture. See *Philosophical Transactions*, No. 237. p. 44.

The Usefulness of Philosophy.

the remedy of *Palmarinus*, which, he asserts, is infallible against the bite of a mad dog in cattel; of a more parable one, also, that serves, no less, in men, the effect whereof was experienced by a near relation of mine; of the antimonial cup, for several diseases in horses and sheep; and, lastly, of another antimonial medicine, very successfully used, by an acquaintance of mine, to fatten his horses after sickness; all these, and many more, receipts of medicines, highly, esteem'd for their efficacy in several distempers, both in men, and brutes, I might here set down, were it my present business.

*And by philosophy
in curing the dis-
eases of the soil.*

Moreover, there are many reasons assignable, why husbandry, with the assistance of philosophy, may be improved, by the addition of a therapeutic part, with regard not only to the animal, and vegetable productions it consists in; but, also, to the various distempers of the ground itself. For, were the causes of barrenness therein, with its respective indisposition to nourish particular plants, or animals, discover'd; many of those defects may, doubtless, be removed by rational applications, and proper means of cure; as we see in other inanimate bodies, and, even, metalline ones. And, from a knowledge of the particular cause of a barren soil, fertility may, perhaps, be procured to it, without much cost. Some ingenious husbandmen have, lately, declared themselves satisfied with a way of meliorating two of the most unfruitful kinds of land, clay, and sand, that consists only in skilfully mixing them, in a due proportion, according to the use for which it is design'd. And, an ingenious gentleman, to satisfy some curious persons, purposely, sow'd some corn, near the place of my abode, which prosper'd so strangely, that one root, whereof I took particular notice, tho', perhaps, not the most productive in the field, yielded sixty odd ears: and, what is more surprizing, this wonderful increase depended only upon a philosophical observation without any thing extraordinary having been done either to the ground, or the seed; for the secret was intrusted with me, by the gentleman himself, to make public, in case he died before me. And, with the same view, he communicated to me a method of increasing the bulk of apples in their growth, by help of the despided leaves of a very cheap, and common vegetable.

*Trades conducing
to the delight of
mankind, improve-
able by philosophy.*

To proceed. Not only the necessary trades, but also the pleasurable ones, are improveable by philosophy; for, they, chiefly, consist in the knowledge, and application, of some natural productions, and operations. And the things, by this means acquired, will, without changing their nature, serve us in different capacities; thus, wine quenches thirst, recovers a fainting person, and intoxicates: the same spirit of wine wherewith the physician draws his tinctures, and prepares his extracts, for medicinal purposes, will dissolve benjamin, for the ladies; which, mix'd with water, makes an excellent cosmetic; and the same spirit, when applied to the proper ingredients, produces several kinds of fine varnish: the tincture of benjamin, likewise, is applicable to the same uses, and is, itself, a pretty odoriferous varnish, and good against tetter, they being bathed therewith. That, knowledge, and skill, may make happy applications, even of unpromising things, to the delight of mankind, appears, evidently, from musical instruments; for, who wou'd imagine, did he not know it, that a few pieces of wood, joined together, and the guts of cats, or lambs, twisted into strings, shou'd, when artificially struck, afford the most ravishing pleasure? I might, here, go on to in-

The Usefulness of Philosophy.

III

stance in the art of colouring, perfuming, confectionary, and of preparing cosmetics, &c. did I not chuse to recommend philosophy, from the pleasure it affords the reason, rather than from the charm wherewith it bribes the senses. Tho' what has hitherto been deliver'd, about the usefulness of philosophy to trades, belongs, chiefly, to those wherein nature herself seems more concern'd than the artificer; yet such are not here exempted wherein art has the greatest share. These, indeed, rather depend upon the manual dexterity of men, than a skilful management of nature's productions, by operating on each other; yet, even here, the naturalist may be serviceable. Many manual trades, especially as exercised in large towns, consist of several parts, and require other trades to prepare, and dispose their materials, before they can be finish'd, and fitted for sale. And, altho' the finisher performs his part, by means of his hands, and tools; yet, the subordinate workmen, usually, stand in need of some observations on the conditions of the body they deal with, or must else employ some physical operation; and herein they may be, greatly, assisted by an intelligent naturalist. Thus, stone-cutting, tho' it seem wholly to consist in shaping its materials, contains many particulars wherein I cou'd, easily, shew that experimental philosophy wou'd be beneficial. For unusual methods might be discover'd, as I can testify, to examine the nature, and goodness, of marble, alabaster, or other stones. A competent knowledge of the sap found in stones, to be employ'd in building, is so necessary, that experienced master-workmen have assured me, that stone dug at one season, will soon moulder away, when the same sort, taken out of the same quarry, at another, will endure the weather for many years, if not ages. The cements, also, and stoppings, as they call them, which are of great use, in this trade, may be improv'd by one who is versed in such kinds of mixtures. I remember, I once taught an inquisitive artist a fine cement, for rejoining broken statues; who, by the like means, in other cases, cou'd counterfeit marble so well, that tho' large cavities were filled up with cement, the work wou'd pass for entire; those parts being undistinguish'd from natural marble. Want of curiosity keeps our stone-cutters in *England*, unacquainted with the ways of working upon porphire: for none of them will undertake, either to cut, or polish, it. Other countries, also, are ignorant herein; tho' it was in great use among the *Romans*; and, even now, at *Rome*, there are a few who make a very great advantage of this art. I am not certain what they employ for that purpose, but believe it to be powder of emery; for I have, in *England*, caused a porphire to be cut by means of that, steel saws, and water. Not here to mention, that I have an art to stain white marble with durable spots, small or large, and of a red, or brown colour. But the art of stone-cutting depending greatly upon the goodness of the steel tools, which they must have from the smith, and the dealers in iron; if these trades were improved, it wou'd tend to the perfection of the other. And, that the smith's craft, however manual it appears, may be meliorated by a knowledge of nature, is not difficult to manifest. The ways of making iron, and steel, are not only improveable before they come to the smith's hands, but better expedients may, likewise, be devised for ordering them, when they come to be fashion'd into weapons, and tools. The sword-blades, and other weapons, made at *Damasco*, are, every where, famed, (and that justly, as far as appears from some

*And particularly
stone cutting-*

And smithery-

The Usefulness of Philosophy.

some trials I have made,) for cutting asunder, even, iron itself; yet, it seems to be, only, the skill of the artificer that gives them this preheminance. Their goodness, indeed, might be presumed to proceed from something peculiar in the materials of that place, did not *Bellonius* inform us, they have no mines of their own; but receive all their iron and steel from other countries; the artists giving them this temper and perfection. In tempering of steel, it is reasonable to suppose, that, besides the goodness of the metal, and the particular degree of heat, which is all the workmen regard; the nature of the fluid, or other body, wherein the hot metal is plunged; and other proper methods of ordering it, may, greatly, contribute to bring it to perfection. I have met with a graver of so surprising a temper, that all the known means, both I, and others, used, could not let it down; though no graver, made in *England*, could have withstood us. This was, afterwards, affirmed to have been tempered at *Damasco*. I am acquainted with a way to harden gravers, without quenching them in any liquor, tallow, or unctuous body; and having recommended, to another, an uncommon method of tempering them, he brought me one, which, being plunged into a certain cheap mixture, had been hardened, and temper'd, at once. And, what may seem more strange, tho' ignition, and extinction, in cold water, be the common way to harden steel; yet, by observing one certain moment of time, steel may, by this means, be made, surprizingly, soft. But farther, a curious maker of steel-tools, told me, he observ'd a difference between the use of pump and river water, in giving them their temper; each being fit for it's respective sort. Besides these, there are many other particulars, wherein iron and steel are improveable by the naturalist. And, first, the metal may be render'd so soft, as, by means of strong moulds, to receive variety of figures. This an eminent artificer assur'd me, he had seen done in iron, with considerable profit. Secondly, it may be render'd fusible; and I, myself, with a charcoal fire, and a flux-powder, compos'd of tartar, sulphur, and arsenic, have run it into an exceeding hard, and very polishable mass. Thirdly, it may be so order'd, as to continue, long, free from rust; and an ancient virtuoso, who purchased the secret, for a great prince, used to shew steel, so prepared by tempering it in water, impregnated with the bark of a certain tree. In a word, there are various other means, whereby iron and steel, or the trades that use them, may be meliorated; for the naturalist may advance an art, or profession, in abundance of respects; as, either, by discovering variety of materials, or, rendering those already in use, better condition'd; by detecting, and reforming, unheeded errors, or mistakes; by devising more easy, and compendious, methods of operation; by improving the auxiliary branches; by instructing the artificer to choose, examine, and preserve his tools and materials; or, lastly, by shewing how to make the ultimate productions sooner, cheaper, easier, or better; applicable to more uses, or more durable than usual; with other services, too numerous here to relate.

Philosophy may introduce new trades.

But farther, a naturalist may, likewise, introduce new trades, as well as improve the old ones; and, that, either, by inventing them originally, or bringing them into request, where they were unknown before: for neither nature, nor human invention, is so far exhausted, as not to afford them, were philosophy employ'd

employ'd in the search. We may here observe, that a trade, in many cases, differs from an experiment, not so much in the nature of the thing, as it's having been, accidentally applied to human uses, or made a business, by a company of artificers, in order to their own profit; which are things extrinsecal and accidental to the experiment itself. Thus, for example, the explosion occasion'd by a mixture of nitre, sulphur, and charcoal, whilst it pass'd no farther than the laboratory of the monk, the reputed inventor of gun-powder, was only an experiment; but, when once the great use to be made hereof became more generally known, and people resolv'd to make a business of improving, and applying it; this single experiment, at once, gave rise to founders of ordinance, gun-smiths, engineers, and abundance of other trades.

The discovery of the polar virtue in the load-stone, has occasion'd a distinct trade, the art of compass-making: and many other instances, of the like kind, might be produced; especially, where mechanical tools and contrivances conspire with the discovery of natural productions; so that, frequently, a very few mathematical theorems, or physical observations, reduced to practice, by the manual operator, become trades. Thus two or three dioptrical propositions, falling into mechanical hands, have introduced spectacles, telescopes and microscopes. Quick-silver being observed to amalgamate with gold, and to be, again, separable therefrom without diminution, produced the art of gilding; which, principally, consists in mixing, by means of a proper heat, pure gold with five, six, or seven times it's weight of quick-silver, 'till it become of a consistence fit to spread upon the silver or copper design'd. For the gold being, by this means, evenly overlaid, they can easily, by fire, force away the mercury; and, with a liquor, by them call'd colourish, wherein nitre, verdigrease, sal-armoniac, and other saline bodies are dissolved, restore it's lustre to the remaining gold, which they, afterwards, make bright by polishing.

The slight, and obvious remark that a spring, physically consider'd, was a continual and durable force, with it's corollary, that this force, properly applied, might balance the weight required to move the wheels of a clock, join'd to a suitable mechanical contrivance, produced those useful machines call'd watches, which now afford a handsome subsistence to many dextrous artificers; and which, tho' custom has render'd them familiar to us, were unknown to the ancients, and highly priz'd, and admired even in *China*, when first carried thither. The discovery that *Aqua fortis* dissolv'd silver and copper, but would not work upon gold, added to the observation, that lead, melted with either of the noble metals, and then forced from them, by fire, will carry off with it any of the baser sort, has, in latter ages, produced the art of refining. The operations of some *Lixivia*, clays, and a few other common things, upon the juice of the sugar-cane, has not only added to the ancient husbandry, the cultivation of these canes, but given birth to the several trades of sugar-boilers, sugar-makers, refiners of sugar, and confectioners; not to mention the advantage it brings to the apothecary. But even a very slight contrivance, or manual operation, if it prove fortunate, may supply men with a trade, as we see in the art of printing. And the lucky trial made to bore very small holes thro' broken *China* cups, with the use of slender wire, instead of thread, or silk, to fasten the pieces together,

The Usefulness of Philosophy.

has given being to the exercise hereof, as a vulgar trade in the *Eastern* countries. Their art, also, of varnishing, or japanning, as we call it, which, depending on a knowledge of some gums, and liquors in their country, employs multitudes of tradesmen among them, is, as I am credibly inform'd, now practis'd at *Paris*. And, finding from *Linchoten*, that in *China* and *Japan*, they made this excellent varnish of gum *Lacca*, I imitated one of the best sorts of it, by dissolving that gum in highly rectified spirit of wine, giving it a colour, and laying it on in a particular manner. I might, farther, alledge, the art of cultivating and gathering sugar-canes, with the manner of ordering their juice, as a recent instance of the transplantation of arts and manufactures; for, as I am very credibly inform'd, it is not long since, that, in our memory, a foreigner, accidentally bringing some sugar-canes, as rarities, from *Brazil* into *Europe*, touched at *Barbadoes*, where an *English* planter obtain'd a few of him, with some hints as to their cultivation and use; which, by the curiosity and industry of the *English* colony there, were soon so well improved, that the island became, and still continues, able to supply *Europe* with sugar. I am the more particular in this instance, because 'tis very remarkable, and shews how many hands the introduction of a physico-mechanical art may employ: for the *Negroes*, who live as slaves upon that spot of ground, and are, almost wholly employ'd in the sugar-trade, amount to between five and twenty and thirty thousand souls. Nay, so prodigiously advantageous is this new art, both to particular persons, and the public, that, one year with another, tho' the island be short of thirty miles in length, there are imported for *England* ten thousand tun of sugar, each tun containing two thousand pound weight; which amounts to twenty millions of pounds of that commodity. This account, tho' it may seem incredible, I have had confirm'd from very good hands.

Thus, then, it appears probable, that experimental philosophy may multiply trades, as well as improve them. Nor do I despair, that among the means of increasing trades, one may be the retrieving of some that were anciently practis'd, but since lost; of which the learned *Pancirollus* gives us a catalogue. For, as the skillful diver brings up, not only pearls and coral, but, also, ship-wreck'd merchandize; so the experimental philosopher dives into the deep recesses of nature, to recover inventions swallow'd up by the injuries of time, as well as to bring to light her hidden riches.

Every profession,
condition, and per-
son, may be bene-
fitted by philosophy.

But, still farther, I am inclin'd to think, there is no profession, condition, or, perhaps, individual person of the species, that may not, one way or other, be advantaged, or accommodated, were all the truths discoverable by natural philosophy, known and applied. So that, besides those inventions which are formed into trades, there may be a multitude of loose particulars, whereby the naturalist might highly gratify, and assist mankind. The nature of the thing will scarce permit me to illustrate this assertion, without descending to instances trifling in themselves, if not contemptible; for which reason I shall, here, content myself with a few.

A great lady, lately complaining that she could not write, in the common way, without blacking her fingers; I desir'd her to prepare her paper with a fine powder, made of about three parts of calcin'd copperas, two of galls, and one

of

of gum-arabic, which, being fresh mixed, and rubbed with a hare's foot, in- to the pores of the paper; when that came to be wrote on with fair water, it would, immediately, discover black legible letters.

Having, several times, occasion to make a word or two, lately written, ap- pear as if written long before, I lightly moisten'd them with oil of tartar *per deliquium*, more or less diluted with fair water, as I desired the ink to appear more, or less, decay'd. Another cleanly way of writing, without ink, is by rubbing the fine powder of exquisitely calcin'd hart's-horn, clean tobacco-pipes, or rather mutton-bones, burnt to a perfect whiteness, upon the paper, and, then, using a silver bodkin, or the like, as a pen. A very simple and easy method of making white table-books, is to temper pulverized ceruse, with a strong soluti- on of gum-arabic, in water, which, being brought to a thick consistence, must be rubbed over the paper, and suffer'd to dry. A very ingenious artificer, having contrived an useful engine, a necessary part whereof was a glass, filled with fair water, and stoppt, complaining that frosty weather, by freezing the water, broke his glass; I advis'd him to use good spirit of wine, instead of the water, or, to save the expence of that, sea-water, strengthen'd with a little salt; or, lastly, common spring-water, with a twentieth, or tenth part of salt dis- solv'd therein; for I have found none of these, tho' clear, to freeze in the sharpest of our winters in *England*. I, once, shew'd a person of quality an easy way to send a written message, which the bearer could not disclose: this, I per- form, by writing on the messenger's back, with a clean pen, dipt in my own urine; (but, to my surprize, the experiment will not succeed with that of eve- ry person) the letters appearing, upon rubbing thereon the black ashes of burnt paper. A confection, made up with the pulp of sloes, accidentally staining a large quantity of new damask, from the top to the bottom, by steeping it, for some hours, in new milk, and, afterwards, causing it to be carefully wash'd in more of the same; the damask came out unstain'd and white. Urine will, usu- ally, take stains, even those made by ink, out of linen; and with strong spirit of salt I have done the same; first wetting the spotted places with fair water, whence, after washing, no iron-mole has remain'd. Some ingenious per- sons who deal much in *Lixivia*, and brines, complaining of inconveniences that attend the trial of the strength of saline liquors, by means of an egg; for, to mention no others, the same egg will, by being kept, grow lighter, and, therefore, when stale, they have, usually, a large cavity at the bigger end; I recommended to them the use of a piece of amber, for that purpose, of what magnitude best suited their occasions. Being once in a place where I cou'd not procure some *Dantzick* vitriol, that I wanted; and obtaining, therefore, some liquor which the rain had wash'd from green vitriol, or copperas-stones, and, adding thereto a proper quan- tity of copper, I made it serve as a menstruum to work upon the metal; and by exhaling the solution, obtain'd the blue vitriol I wanted. And the like, I doubt nor, may be done with all those common green vitriols made of iron, wherein the saline part is not too much satiated with the ferruginous. A great dealer in cyder expressing a desire to be able to make that liquor stronger, so as to keep longer than ordinary; I told him, to infuse, for twenty-four hours, in ten or twelve gallons of the juice of apples, about two bushels of the same kind

The Usefulness of Philosophy.

of fruit, grossly bruised; then, gently pressing them, to repeat the infusion; observing not to make it too thick: and this succeeded excellently. Searching accidentally in a dark place, where stood some chymical glasses, I knew nothing of, negligently stopped, and not wrote upon; one happen'd to fall, and grievously stain a new suit I had on: but judging, from the nature of the stain, that it proceeded from some acid spirit; by searching about, and smelling to the remaining bottles, I found one that I guess'd, by its scent, to abound with volatile salt; and with this liquor I bath'd the stain'd parts, which immediately restored them to their former colour. By the like means, also, I have presently remedied the discolourations made in garments, by fretting liquors; which wou'd, otherwise, have been thereby render'd unfit for wearing. Discoursing, lately, with a states-man, of the means whereby well-meaning persons may be injured and defamed, I said, there was a way to take clear out of a parchment-writing all the words it contain'd, so that one might, by leaving the name, substitute what one pleas'd. And to satisfy him hereof, I did, in a few minutes, take off from parchment all that was written thereon; without defacing the parchment. Some attempt to do this on paper with *Aqua fortis*; but that, by discolouring the paper, gives a suspicion of the trick. But, as for the perfect way of performing this experiment, with others of the like nature, which I have sometimes, out of curiosity, successfully made; I think it much fitter to conceal than communicate them; because, shou'd they fall into the hands of persons inclined to misapply them, they might greatly disturb human society. A virtuoso, having made a solution of gold, suspected the metal alloy'd with copper, and therefore unfit for his purpose; I advis'd him to precipitate the gold by an urinous spirit, which it did, into a fine calx, while the fluid, remaining highly tinged with blue, betray'd the copper that had been used as alloy.

These trifling instances being more pertinent to my design, than others, in themselves of greater value, is the reason I have chose them; nor shall I repent the mention of them, if they serve to shew, that the meanest experiments may sometimes be useful, and better adapted to convince strangers to philosophy of its numerous uses, than those of a higher and abstruser nature. As, to know the use of a bladder of air, may be more serviceable to a pilot in a ship-wreck, than the most hidden properties of the magnet; so, in some cases, obvious and slight experiments prove vastly more welcome and useful, than more considerable ones wou'd at another time: so true it is, that "every thing is beautiful in its season." For my part, I cannot but hope, that natural philosophy will prove daily more serviceable both to particular persons, and trades themselves; especially if a farther enquiry be made, and thereby new qualities detected, and unheeded uses of natural and artificial philosophy discover'd. For whoever narrowly considers it, will find, that trades, at present, deal with but very few of nature's productions, in comparison of those they leave unemploy'd; and that, what they do make use of therein, are their obvious qualities, bating some few more secret properties which chance, or a lucky sagacity, rather than skill and enquiry, have discover'd; and, therefore, I scruple not to assert, that if men were thoroughly sensible of their own interest, and wou'd carefully keep their eyes open upon the properties of things, and the application that might be made thereof, in human life;

life; they might not only discover new qualities thereby, and so produce new trades, but even convert them to such uses as the inventor little imagin'd: and of this I might produce various instances.

To these general considerations, I must add, with regard to the following, that the reader is not to expect a methodical enumeration of all the grounds and motives I have to expect great advantages from a future progress in the knowledge of nature for I choose to confine myself to what I can render probable by examples, and instances of that which is already acquired, or, very likely, soon will be. It must not, therefore, be imagin'd, that I have overlook'd all the particulars pertinent to my subjects; nor that I propos'd to set down all the inducements that might be brought to shew the usefulness of experimental philosophy. My design is only to render the expectations of advantages to be receiv'd from it probable; to do which, is taking a good step towards the attainment of the things themselves, as Sir *Francis Bacon* well observes. And I, the rather, endeavour to heighten mens expectations herein, because many there are, who, being bred up in the vulgar barren philosophy, judge of all philosophy by that; and because some morose authors, and despondent persons, who have unsuccessfully attempted to perform things deliver'd by unfaithful writers, fancy, and wou'd persuade others, that nothing considerable is performable by natural philosophy; our forefathers having, if we credit these persons, had the good luck to hit upon all the profitable inventions which philosophy can afford mankind. It may here, also, possibly be expected that I shou'd treat particularly of the principal means whereby a naturalist might advance trades, and assist mankind to recover part of his lost empire over the works of nature. And I confess I have had thoughts of a project to advance experimental philosophy, consisting of such heads as these. A prospect of what may probably be attain'd to by philosophy, both in theory and practice. A brief account of what is already obtain'd thereby. The imperfection of our present attainments. What helps we now enjoy. The insufficiency of our present helps. The hindrances and causes of them. And, lastly, the means and helps that may be applied. But I did not here propose a just treatise; only to register some loose and scatter'd experiments and observations.

S E C T. II.

WERE it allowable for none but great mathematicians to discourse of mathematics, I might be accused of presumption to engage in it; for the authority of some famous modern naturalists prevented my making any extraordinary progress in that study, by absolutely denying it to be useful in philosophy. But a knowledge far inferior to that of *Archimedes*, or *Apollonius*, may serve to shew the advantages of mathematics in the contemplation of nature. Lest others, therefore, shou'd be influenced by the like authorities, I shall enter a little into this subject. I know the extravagant opinions of *Kepler*, and other great mathematicians, are pleaded against the usefulness of mathematics in natural philosophy;

*The usefulness of
mathematics to
philosophy.*

*The Usefulness of Philosophy.**In improving the mind.*

lophony; yet, from reflecting upon several mechanical experiments, I discover'd how serviceable it might be made thereto: and, therefore, I have often wished, I had employ'd upon the theory most of that time I spent in the practical part of this science. For a competent knowledge in mathematics is so necessary to a philosopher, that I scruple not to assert, greater things are still to be expected from physics, because those who pass for naturalists, have been generally ignorant in that study. Now, mathematics may be, particularly, assisting to philosophy in many respects besides those general advantages which they bring to the minds of men, whatever be the studies whereto they addict themselves; and, consequently, to the philosopher*. For, in general, they make men accurate, and attentive to what they are about, by keeping their thoughts from wandering, and enuring them to patience in going thro' tedious and intricate demonstrations; and thus they greatly improve the reason, by habituating it to deduce successive consequences, and judge thereof, without readily acquiescing in any thing but demonstration. But the operations in algebra seem to afford one of the clearest exercises of reason; nothing being therein performable without strict and watchful reasoning; whilst the whole method, and the several steps, appear at one view, when the operation is finish'd. Before I descend to the particular uses of mathematics in natural philosophy, let it be observed, first, that the phenomena which the mathematician concurs to exhibit, really come under the cognizance of the naturalist; for when matter is endow'd with qualities, the consideration how it came by them relates rather to the agent or efficient, than to the nature of the body itself. Thus the image made by a mirror, tho' that be an artificial body, falls under the consideration of the naturalist, as well as when the like image is presented by calm and clear water; and artificial rain-bows have as just a title to his contemplation, as that form'd in the clouds. The same may be said of echoes. And, indeed, such kind of phenomena usually require the same solutions, whether human skill intervene or no, in their exhibition. And secondly, that, as we formerly said, man's power over the creatures depends chiefly on his knowledge of them; and therefore whatever serves to encrease his knowledge, is likely to encrease his power. These two observations being premised, I come to particulars.

Teaching the figures of bodies.

Mathematics, then, teach men the nature and properties of figures, both in surfaces and solids, with the relation between the superficies and solidity of the same body. Matter is, indeed, the subject of the naturalist's speculations; but if all the operations thereof depend upon the modifications its local motion receives from the magnitude and figure of its parts, it cannot be doubted, but the knowledge of what figures are more or less capacious, more or less proper for motion, penetration, resistance, &c. must be of considerable use in explaining many phenomena of nature: but the doctrine of figures is wholly learnt from the geometricians, who treat expressly of triangles, circles, ellipses, parabolas, hyperbolas, spheres, cones, cylinders, prisms, pyramids, cubes, &c. and thereby intimate the figures of other bodies compos'd hereof, or bearing some analogy to them. There are various

* Nothing can more powerfully recommend the study of mathematics, than to know, that the grand discoveries of Sir Isaac Newton are made by means thereof; and were without that assistance impossible.

properties

properties both of plain and solid figures, with their relations, particularly such wherein motions are made, the knowledge whereof may be of great use both to the speculative and practical naturalist. To know the proportion which *Archimedes* has demonstrated between a sphere and a cylinder; of both these to a cone; that a pyramid is the third of a prism with the same base and altitude; in a word, to know the proportions between the geometrical bodies, may be useful in cases where one, and not another of them, is procurable. We have an instance hereof from *Ghetaldus*, who cou'd not procure an exact metalline sphere, wherewith to examine the proportionable weight of bodies of the same bulk; and therefore, in its stead, made use of a true cylinder, which was easily attainable; having learnt from *Archimedes*, that a cylinder, whose base equals a great circle of a sphere, and height, the diameter of the same, is to that sphere as three to two; subtracting, therefore, a third part of the whole weight of his cylinder, the remainder gave him the weight of the sphere he desired: and this being once obtain'd, he thence deduced the weight of other spheres he had occasion to employ, in the construction of those tables, that have been greatly used by succeeding mathematicians. And I my self have, also, made applications of this same theorem of *Archimedes*. Since *Galilao* and *Torricelli* have demonstrated, that projectils, in their motion, describe a parabola; it must be of service in the art of gunnery, and other cases, to be well acquainted with the properties of that figure; which is, also, thought capable of performing wonders in *Specula*, cou'd they be ground thereto: for all the rays of light, falling then parallel to the axis, they wou'd be reflected from the surface, to a point, or focus; where, if the glass, or metal, be large, the heat will be more intense, than from a spherical glass of equal magnitude. But I shall not, here, insist upon the numerous diverting experiments to be made in catoptrics, by means of spherical, cylindrical, and other kinds of reflecting glasses.

Even pure mathematics, exclusive of the advantage it brings to the mixt, may be greatly useful in human life, and to experimental philosophy. The properties of arithmetical and geometrical progressions, in numbers, seem foreign to the business of shops and ware-houses; yet, by a knowledge of the double progression, beginning with an unit, as, 1, 2, 4, 8. wherein the consequent is always double to the antecedent, much trouble and expence may thereby be saved; for, with three weights, all the pounds from one to seven, inclusive, may be weigh'd; and with four, all those not exceeding fifteen: and from this observation proceeds the division of some sets of weights used by our goldsmiths. But if weights are to be used in both scales, to reduce them to an equilibrium; the triple progression, as, 1, 3, 9. has a more notable property, from the consideration whereof, *Stifelius* concluded, that, by three weights, any number of pounds may be weigh'd, from one to thirteen, inclusive; with four, any number from one to forty, inclusive; with five, any not exceeding a hundred and twenty-one; and with only six weights, all the pounds from one to three hundred and sixty four. But the method of ordering so few weights, to serve so many purposes, is best found out by algebra; and being as well applicable to the parts of pounds of different denominations, it may be serviceable to those who make statical experiments. The *Regula combinatoria*, likewise, tho' not fully explain'd by the modern algebraists, will,

Dividing
weights.

The Usefulness of Philosophy.

will, if I mistake not, when symbolically managed, and skilfully applied, be very serviceable to the naturalist, on certain occasions.

In framing hypotheses.

We may next observe, that mathematics will greatly assist the naturalist in framing hypotheses, and judging of those advanced by others. What wretched theories even famous naturalists may run into for want of this knowledge, appears from the accounts which *Epicurus* and *Lucretius* give us of the celestial bodies. And, indeed, what satisfactory account can be given of the varying lengths and vicissitudes of days and nights, eclipses, the stations and retrogradations of the planets, and other astronomical phenomena, without mathematical knowledge? And without the doctrine of the sphere, what naturalist can tell, which is the true system of the world, the *Ptolemaic*, *Tychonic*, or *Copernican*? Without arithmetic and geometry no knowledge can be had in astronomy, especially not of the intricate theories of the planets; yet, this science cannot be too highly prized, that tells us our earth is but as a center to the immensely distant sphere of the fixed stars.

Shewing the true system of the world.

The usefulness of pure mathematics to geography is evident; and, surely, no inquisitive person will despise arts, which, alone, can shew us, whether the earth we inhabit moves, or stands still. But there are various phenomena of nature, neither astronomical, nor geographical, wherein the usefulness of mathematics is visible; for, as to phenomena of vision, what a pitiful account have we of it from the *Aristotelian* philosophers, physicians, and even famous anatomists, who were strangers to geometry, in comparison of the modern mathematicians? And whoever is acquainted with dioptrics, must be sensible, that a knowledge of the properties of convex bodies, the laws of refraction, and the doctrine of conic sections, are required to explain most of the phenomena in vision. A stranger to this part of mathematics will scarce understand the admirable structure of the eye; how the crystalline humour refracts and converges the rays of light that come from the object, to paint the picture upon the *Retina*, in the bottom of the eye; why that picture, by reason of the crossing of the rays, is there inverted, tho' the objects themselves appear erect; why small objects, placed near the eye, and seen under a greater angle, seem as large as bigger, that are more remote therefrom; and much less will he comprehend the reason of many delusive appearances exhibited by concave, convex, conical, and cylindrical glasses.

The laws of optics.

The doctrine of ratios.

And since from the magnitudes of different bodies, or the various parts of the same, and their degrees of velocity in motion, a certain relation will arise, called *ratio*, or proportion, the doctrine whereof is the noblest part of mathematics; he, who is not indifferently skill'd in this science, has laid but a poor foundation for philosophy. The fifth book of *Euclid's Elements*, where the doctrine of proportions is principally deliver'd, may, perhaps, prove more instructive to a naturalist, than the fifth book of *Aristotle's physics*. No wonder, then, that *Plato*, by an inscription placed over the gate of his school, forbid entrance to those unskill'd in geometry; as being unfit to judge of what he taught. Nay, there are some considerable phenomena of nature, which will remain unintelligible to those who know nothing of the doctrine of proportions. Thus, when 'tis said, in optics, that light decreases, in a duplicate proportion of its distance from the illumin'd body, a person unacquainted with proportions cannot affix any meaning to this theorem; much less could he know the truth thereof. So when the same

propo-

proposition is by *Mersennus* applied to sounds, a common reader wou'd remain in the dark, did not the author add, by way of explanation, that if, for instance, the sound of a piece of ordinance be heard at a league's distance, the said sound wou'd be heard four times stronger at the distance of half a league. Nor will this example itself give such a reader, as we speak of, a clear idea of the proposition. We have a more considerable instance of this kind from the noble discovery made by *Galileo*, that when a heavy body descends in the air, the spaces thro' which it passes, are, from the beginning to the end of its fall, in a duplicate ratio of the equal parts of time spent in falling; for he observed, that a brass bullet, of an hundred pound weight, descended, in the space of one minute, an hundred *Florentine* cubits, or one hundred and eighty *English* feet; but then it falls in such a ratio, that it's velocity encreases in a progression of odd numbers, beginning from an unit; so that if in the first moment the weight fall one fathom; in the second, it will fall three; in the third, five; in the fourth, seven, &c. whence *Mersennus* gives this general rule: "if the times be given to find the spaces, square the former, and you'll have the ratios of the latter; but if the spaces be given to find the times, the root of the spaces will give the ratio of the times." Another instance, to shew the use of mathematics to a naturalist, may be taken from statics, where, in the balance or lever, the proportion between equivalent weights, and their distances from the prop, is reciprocal; whence, with the stilyard and a single weight, a considerable number of pounds may be weigh'd. But this grand theorem with others, that also serve to explain the phenomena of motion, cannot well be understood without an insight into geometry, and the doctrine of proportions. And that mechanics may vastly assist the naturalist, will be readily allow'd, when 'tis known how many of nature's works are engines, and operate accordingly.

The doctrine of proportions, as it is the soul of mathematics, so it may become prodigiously serviceable in philosophy also; and that not only by assisting the naturalist to understand, as we have seen, many phenomena of nature, but as it may enable him to perform what he otherwise cou'd not. The pendulum is the most accurate instrument we, at present, have for measuring short spaces of time; but he who wou'd know the due length of one to swing any determinate space, as half a second, for instance, must find it out by trial and observation, unless he be acquainted with the doctrine of proportions; whereas, if that be understood, and the phenomena of pendulums, he may, from the length of one that measures a known part of time, deduce the length of others to measure different parts thereof; without making any new trials or observations. Thus, according to *Mersennus*, a string, with a bullet fix'd to the end of it, the length whereof, including the bullet, is three feet and a half, vibrates seconds; * and it is a known theorem, that "pendulums, alike in every thing but length, have their lengths in a duplicate proportion of their respective times of vibration, or as the squares of their vibrations in the same time;" whence the times are in a subduplicate proportion to the lengths of the pendulum: if a pendulum,

* According to *M. Huygens*, the length of prop. 25. Or, according to common use, the pendulum that vibrates seconds is 3 *French* among us, 39, 2 inches. feet. & $\frac{1}{2}$ lines. *Horolog. Oscillator.* Part. 4

The Usefulness of Philosophy.

therefore, were desired to vibrate half seconds, it must not be a foot and three quarters long, which is half the length of one that vibrates whole seconds; for that wou'd be much too long; nor cou'd it sometimes, for want of a standard, be discover'd how great the excess was: but as the proportion between a second and half second is double, and the proportion between the length of the two strings must be duplicate of that of the times; it follows, that the length of the strings must be, as 4 to 1, which is duplicate of 2 to 1; so that the string, to vibrate seconds, ought to be but a fourth of the length of the other. And this appears from other calculations, and experience itself.

The art of composing the vast variety of tunes that render music so delightful, depends upon the doctrine of proportions; and whoever is well skill'd herein, and can apply it to notes or words proposed, according to the observations of the gratefulness of particular consonancies, may of himself compose a great variety of new and pleasing tunes, which are so many instances of his power.

Mathematics may suggest new experiments,

Perhaps, also, mathematics may suggest to the naturalist many new experiments whereby to vary those already made concerning the figures of bodies, the lines of motion, numbers, proportions, and the like; for 'tis probable, that suggested experiments as wou'd either be overlook'd, or unskilfully proposed, for want of mathematics, will either immediately, or by means of their applications, prove serviceable to mankind. What numbers of experiments and observations in the destructive art of gunnery have been proposed and made from hints suggested by mathematicians? * But these I leave, and come to their less pernicious discoveries. Pure mathematics have help'd to discover, and derive from familiar observations, a great variety of phenomena. From observing, that the rays of light are refracted in passing thro' different mediums; and that, in particular circumstances, the sun and moon will be eclipsed at particular times, very considerable deductions have been made by mathematicians in optics, astronomy, geography, navigation, and chronology. And whoever considers the doctrine of proportions, of concords and discords, with the great number of musical instruments they have occasion'd, and the other kinds of hints they may afford; and is, at the same time, acquainted with those ingenious and useful experiments in optics, derived from observing that the angle of incidence made by the rays, is equal to that of reflection; that on curve surfaces the angle may be estimated as made by a tangent thereto; that the rays passing from a rarer medium into a denser, are refracted towards the perpendicular; but, out of a denser into a rarer, from the perpendicular; whoever, I say, considers all this, and how great a variety of propositions have, by the mathematics, been deduced from these few observations, cannot but grant what, by so many instances, I have endeavour'd to prove. † To conclude this subject; many practical points of doctrine reckon'd among mixt mathematics, may assist the naturalist in making experiments and observations, which he cou'd either not at all, or but imperfectly, make without them; thus,

* For a complete theory of the whole art of gunnery, deliver'd in a few propositions, see *Philos. Transf.* N^o 179. p. 9. Or, rather, the posthumous works of Mr. Cotes, lately published by his worthy successor in the Plumian chair. † Upon these, and a few other properties of light, demonstrated by others, and taken for granted by Sir Isaac Newton, that great philosopher, has rais'd his wonderful theory of light and colours.

dialling, for instance, teaches to measure time, and tends chiefly to practice; the art of perspective is of great service in representing solids and distances upon small and plain surfaces; as also in limning; and with this both scholars and travellers wou'd do well to acquaint themselves, in order to represent and adorn the history of nature, and several parts of navigation. But if it be undeniable, that in these, and other instances, mixt mathematics are of use to the naturalist, and enable him to extend the empire of mankind; 'tis certain, that pure mathematics must be so too; since 'tis from the theory, that not only these more practical parts are derived, but a greater number of mixt mathematical sciences may take their rise. Music consists of pure mathematics and sounds, hydrostatics of mathematics and water; so that by an union thereof, with other subjects, the doctrines of mixt mathematicks will probably be advanced, both in number and usefulness. Nor is it only upon the foresaid parts of learning wherein useful applications of pure mathematics may be made: other sciences have a great dependence on these sublime ones, and particularly those which, in a large sense, are call'd mechanical, whereof we come next to treat.

S E C T. III.

BY mechanics, I understand not simply the doctrine of the moving powers, or the method of improving force, and forming engines; but in general, all those parts of knowledge that consist in the application of pure mathematics to produce or modify motion in bodies. * That this science, therefore, is

* 'Tis a just notion of mechanics which Sir Isaac Newton delivers in the preface to his admirable *Principia*. "The ancients," says that great author, "made two kinds of mechanics, a rational and a practical. For the manual operator, usually performing his part inaccurately, gave occasion to distinguish between mechanics and geometry, and so to refer whatever is perfect to the latter; but what is less perfect, to the former. The error, however, is not owing to the art, but those who practise it. Whoever works inaccurately, is an imperfect mechanic; but cou'd a man perform to the utmost exactness, he wou'd be a perfect mechanic. To describe right lines and circles, in which geometry is founded, belongs to mechanics; and geometry does not teach to draw them, but supposes them to be drawn; for it requires that the student shou'd exactly describe them before he enters upon geometry; and afterwards shews how problems may be solved by means of these operations. To describe right lines and circles are problems, but not geometrical ones; the solution of them being sup-

posed from mechanics, and their use, when solved, taught in geometry. — Geometry, therefore, is founded in the practice of mechanics, and is only that part of universal mechanics, which with accuracy proposes and demonstrates the art of mensuration. But manual arts being principally employ'd in giving motion to bodies, geometry is commonly confin'd to magnitude, and mechanics to motion. And in this sense rational mechanics is an accurate exhibition and demonstration of the doctrine of motions, from whatever powers they proceed, and of the powers necessary to all motion."

"The effects of machines," says that excellent mathematician C. Wolfius, "following upon their structure by unalterable laws of nature, all operations of bodies are call'd mechanical, because they act agreeably to their structure, and the eternal laws of motion. He, therefore, is a mechanical philosopher, who plainly shews, by the laws of motion, how the effects of things follow from their structure." *Wolfij Element. Mechan. p. 642.*

The Usefulness of Philosophy.

greatly advantageous to experimental philosophy, and to enlarge the empire of man, appears, in that many of those things above shewn to render mathematics useful to the naturalist, may, *mutatis mutandis*, be understood here also; tho' this science has some peculiar advantages. To come to particulars. The phenomena of this doctrine belong to the history of nature in its full extent, and therefore challenge the naturalist's consideration; so that being thoroughly understood, we may well suppose it will greatly contribute to the advancement of his knowledge, and consequently of his power. Thus, for instance, when a piece of wood plunged in water emerges and floats, even vulgar naturalists think it belongs to them to account for this phenomenon, which they fancy proceeds from the positive levity of the wood; tho' some woods that swim in water, may sink in oil or spirit of wine. And may not a philosopher find out the reason, why one part of floating wood keeps above the surface, whilst the other sinks beneath it; and why the extant part of different kinds of wood bears different proportions to that immersed, in the same or different waters? For if these, and the like phenomena, be carefully examin'd hydrostatically, the cause thereof will not only appear; but also, by applying that discovery, an easy way is obtainable to estimate the different strengths of salt-springs, brines, and lixiviums, with other practical corollaries.

By helping to invent and judge of hypotheses.

Mechanics, also, help to invent, and judge of hypotheses relating to the subjects wherein they are concern'd. This appears not only in the screw, the crane, the balance, &c. but in many familiar phenomena, wherein this doctrine is usually thought little concern'd; as the bearing a pike, or musquet, on the shoulder; the force of a stroke given with a long or a short instrument, or held it in a particular posture; the power of a ship's rudder; the rowing of boats; the breaking of wood; with a multitude of other common and obvious instances, whereof mechanics will furnish us with a better account than the schoolmen, and such as are ignorant of the properties of the centre of gravity, the several kinds of levers, the wedge, &c.

And solve phenomena; as, particularly, in hydrostatics.

But there are many things in physics that cannot be well explain'd, nor understood, without the assistance of mechanics; for, abundance of phenomena, the physical causes whereof may be assign'd by the naturalist, cannot be justly and properly deliver'd without a knowledge in statics, hydrostatics, &c. as appears by the above-mention'd examples of the floating and sinking of wood in water; for, were the reason of this appearance demanded of a school-philosopher, he wou'd answer, that wood, abounding with air, an element much lighter than water, that detains it upon the surface of the fluid. But this reason is not satisfactory to a naturalist versed in hydrostatics. For, not now to examine whether there be such a thing as positive levity, or whether the air possesses that quality, experience shews, that tho' when wood is lighter than an equal bulk of water, it will swim; yet if it be heavier, it sinks therein; as guaiacum, wherein I the rather chuse to instance, because the chymists observe it leaves less ashes (in which the terrestrial and heavy parts are supposed to reside) when burnt, than other woods which float on water. Iron and stones, by reason of their weight, are thought to contain little air, yet they rise or float if immersed, or plunged in a fluid specifically heavier than themselves; as any one may try with quick-silver or melt-

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ed lead; from whence it appears, that the predominancy of the air need not be regarded in bodies, when consider'd as to their sinking or swimming in a proposed fluid. And tho' air were admitted as the cause of a body's floating, it cou'd only be a remote one; the immediate cause being, that the body is lighter than an equal bulk of the fluid; and, therefore, the same body, without acquiring or losing air, may swim in one water, and sink in another; as loaded ships have been found to do upon coming into fresh water: and an egg that sinks in common water, will be sustain'd in strong brine. Nay, a body may be so poised, as to sink if the fluid grow warm, and emerge again when that becomes cold. But if the levity of the air cannot account for the floating and sinking of wood, much less will it afford a satisfactory reason, why different kinds of wood, in the same water, or the same kind in different waters, will sink to a certain depth, whilst this phenomem is easily solved from hydrostatics; for, according to *Archimedes*, "solids lighter than the fluid they are put in, will sink, till a quantity of the fluid equal in bulk to the part immersed, becomes equal in weight to the whole floating body;" from whence flow these corollaries. A floating body bears the same proportion in weight, to a quantity of fluid equal to it, in bulk, as the immersed part of the body bears to the whole of the same body. A quantity of fluid, equal in bulk to the whole body, has the same proportion, in weight, to the said body, as the whole body has to the part below the surface of the fluid. And as these corollaries determine the proportion between the immersed and extant part of the floating body, they suggest a way of contriving a small and light floating instrument to measure the different gravities of several liquors. And hence, also, *Stevinus* shews, that if the part of a floating body immersed in a fluid be known, together with the specific gravity of that fluid, the weight of the whole solid, how large soever, may be determin'd. Thus, suppose the part of a ship lying under water be 100,000 cubic feet, and that each cubic foot of water weighs 70 pound, multiply 100,000 by 70, and the product, 7,000,000, gives the weight of the ship, and whatever is contain'd therein. Ask a mere school-philosopher, why sucking-pumps will not raise water above the height of 40 feet; or why, when a proper quantity of water and quick-silver is poured into an inverted syphon, the surface of the water in one leg will rise vastly higher than the surface of the quick-silver in the other; or, lastly, why, tho' a piece of iron, and another of marble, be equiponderant in the air, the metal appears much heavier than the stone when the scales are plunged in water; and, I fear, he will hence receive more perplexity, than you satisfaction. It were easy to add a multitude of queries whereof a naturalist, ignorant in mechanics, cou'd give but a very poor solution; which yet the mechanic wou'd satisfactorily answer. And for proof hereof, I refer the schoolmen to *Aristotle's* mechanical questions. But to shew, that some physico-mechanical phenomena are unintelligible without a knowledge in mechanics, I shall produce a considerable theorem in hydrostatics, thought to be first deliver'd by *Mersennus*. "The velocity wherewith water descends and runs from tubes of equal bores, but unequal heights, is in a subduplicate ratio of their heights:" whence we have this corollary, that such tubes are in a duplicate ratio of the velocity of the water that subsides in, and runs out of, them; so that to make one cylindrical tube

Mechanics will
assist to multiply
experiments.

tube of the same bore with another, run, in equal times, twice as much water as that other, the former must be four times the length of the latter.

And as was said of mathematics, so also mechanics will assist the naturalist to multiply experiments by the enquiries they will suggest, and the inferences and applications whereto they lead. Hereof we have a noble instance in the *Torricellian* experiment, wherein almost every year produces new discoveries. *Mersennus*, also, has supplied us with abundance of new propositions in balistics. But *Galileo* affords us still more noble examples, relating to the resistance of bodies in breaking; the force required to break them; and the length whereat their own weight will do it; which he has reduced into an art. 'Twere needless to add farther particulars on this head, considering what a variety of useful propositions have been deduced, and are still mechanically deducible, from that observation of *Archimedes*, "that a solid body weighs less in water, than in air, by the weight of a quantity of water equal, in bulk, to that body." And that many mechanical theorems are fertile both in other propositions and useful applications, I may hereafter shew, by the uses I myself have made of this very proposition, and its corollaries.

The peculiar uses
of mechanics, in
centrobarricks.

As for the peculiar uses of mechanics, they consist in the making proper instruments and tools for experiments and observations; and of this we have a remarkable instance in the mariner's compass, whence the benefits of navigation are derived. *Baptista Porta*, and others, ascribe the discovery of the needle's directive faculty to *Amalphi*, a *Neapolitan*; yet that author owns, that for want of our present contrivance, this lucky inventor used a piece of wood, or straw, to keep his needle afloat; which was a very inconvenient shift: and had mechanics never supplied us with a way to poise the needle, so as to keep it horizontal, notwithstanding the rolling motion of the ship, the effect of the load-stone would have continued very insignificant to the distress'd pilot. 'Tis mechanics, also, that, by means of the centrobarric doctrine, has enabled us to make the dipping-needle; whose phenomena are [very odd: and tho', as far as I have try'd, they seem very uncertain; yet it may very possibly happen, that farther observation will reduce them to some theory, productive of practical inferences.*

That centrobarricks may be of immediate use, will appear more credible, if, as writers of unsuspected veracity assure us, a kind of lamp has been made, and poised so, that tho' rolled about like a bowl, the oil will not be spilt, nor the

* The dipping-needle seems, since the time of *Mr. Boyle*, to have been applied to little else than the discovery of iron-mines; till *Mr. Whiston* happen'd to consider it, and attempted to apply it to a much more noble purpose; the discovery of the longitude at sea. He observes, that if it be 6 inches radius, of a prismatic or cylindrical figure, and oscillates along the magnetic meridian, it here performs every mean oscillation in about 6", and every small one in about 5"; but that if it be 4 feet long, it makes every mean oscillation in about 24", and every small one in about 22"; that the force of magnetism in this country, as it

affects needles of a foot in length, is to that of gravity, nearly as 1 to 300; that the quantity of magnetic power, accelerating the same dipping-needle, as it oscillates in the same vertical plains, is as the co-sines of the angles made by those plains, and the magnetic meridian, taken on the horizon; and, that the times of oscillation and vibration in dipping and horizontal needles, equally good, are as their lengths directly; and the actual velocity of their points along their arcs always equal. See *Whiston's Dipping-Needle*.

flame extinguish'd. To remedy the inconveniences of *Cardan's* lamp, I contrived one after the following manner.

ABCD, is a vessel of latton, well folder'd every where.

BC, EF, are two bottoms folder'd to that vessel.

FG, is a pipe folder'd to the bottoms; and whose aperture is in the great cavity *FA*.

H, is a hole in the pipe *FG*, opening between the two bottoms, *BC, EF*.

I, is another hole, to which is folder'd a pipe *IG*, bent upwards, at *G*.

PP, is a little vessel fit to receive the wick of the lamp.

LM, is a slender pipe, open at both ends, and folder'd to the cover *AD*, in *L*; and to the bottom *EF*, in *M*. So that by this pipe the external air may communicate, between the two bottoms, without penetrating into the cavity *AF*.

N, is a short pipe, folder'd to a hole in the cover *AD*, whereby oil may be poured into the cavity *AF*, and that be stopp'd afterwards very close with cork.

For the filling up of this engine, you must stop the aperture *G*, of the pipe *IG*, with a long pin fitted for that purpose; and the upper end of the pipe *LM* must be stopp'd too; then pour in your oil by the aperture *N*; which done, the same aperture *N*, is to be shut up exactly, and both the other to be opened, viz. *G*, and *L*. Then the oil, through the pipe, *IG*, will run and fill the vessel *P*, till its superficies is in the same level with the hole *H*, and no more, as might be easily demonstrated.

Now it is easy to see that this lamp is free from all the inconveniences which the lamp of *Cardan* is subject to; for

1. The air doth not get into it by starts or gluts, as it doth in *Cardan's* lamp; but when the oil in *PP*, being wasted by the flame, comes to have its superficies lower than the hole *H*, the oil from the cavity *AF*, runs into *PP*, gently, because its place left in the cavity *AF*, is easily supplied by the external air, which through the pipe *LM*, and the hole *H*, gets up into the said cavity *AF*.

2. When the air contained in the cavity *AF*, comes to be rarify'd by some heat, it drives out much oil, and so is able to choak *Cardan's* lamp: but in this, the oil being thus driven out, gets into the space between the two bottoms, as well as into the vessel *PP*. Now the said space between the two bottoms, by reason of its largeness, receiving twenty or thirty times more oil than the vessel *PP*; it follows, that the superficies of the oil therein riseth twenty or thirty times less than if all the oil had been driven into the said vessel. Therefore, when we fill the lamp, we must take care that the pipe *L*, be well shut, so that the air between the two bottoms, finding no issue, may keep the oil from filling that space, which by this means, when the hole *L*, is open, will be fit to receive the oil driven out by the rarification of the air in the cavity *AF*.

3. The oil being always kept at the same distance from the flame, the wick will not be quickly consumed.

4. We here have the conveniency to put new oil into the lamp, without moving or extinguishing the same; for we you need but shut up *G*, and *L*, and pour the oil through *N*, as was said before.

From

Fig. 1.

*In the art of
diving.*

From knowing that compress'd air has a spring whereby it resists farther compression, and by a slight contrivance to apply this pneumatical principle, an acquaintance of mine made an engine, wherein he cou'd dive to the bottom of the sea, and there continue sometimes many hours, till wrecks, or things of value, were found, and cables tied to the sunk guns of ships, which were afterward buoy'd up.* And by this means he acquired great riches.

*And the use and
application of
valves, schemes,
models, &c.*

But so many examples might be given of mechanical instruments and tools useful to the naturalist, that it wou'd be tedious to enumerate them; nor is it necessary, since the shops, by exhibiting them, may well save us the labour. But as a knowledge in mechanics helps the naturalist to proper inventions, according to his several purposes, so one good contrivance may equal, and, perhaps, produce many useful experiments. He must certainly be a dull naturalist, who can know the properties of the centre of gravity, of levers, balances, screws, wedges, &c. and, by frequenting the shops, have seen various engines to answer different designs, and not be able, by compounding, varying, and improving them, to devise means he wou'd otherwise not have thought on, to make new trials, or to repeat the old ones with more accuracy, ease, and some other advantages. And, that a good mechanical contrivance may be as valuable as many particular experiments, will appear from examples. To valves, tho' a slight and obvious invention, we owe not only a great variety of pumps, and bellows; but they also make very considerable parts of many other engines; and may, as some trials have inform'd me, be employ'd in several new experiments; especially when made of brass, and so small, as some I have obtain'd from skilful workmen, that they may be used in little glass-pipes and syringes. By means of small valves, and the knowledge of the spring of compress'd air, wind-guns have been contrived; which serve to shew the weight of the air, as well as to kill deer, or other game; without frightening away the rest by any report.

*Mathematics and
mechanics too much
confined in their
application.*

But, methinks, both mathematics and mechanics have been too much confin'd to the stars, the earth, the water, and some few conspicuous parts of nature besides; whilst they might be extended by a philosopher to various other productions, both of nature and art. Thus *Archimedes* deduced hydrostatics from the application of vulgar statics to the weighing of bodies in air and water, or water alone; and *Torricelli*, with others, lately applied the principles of hydrostatics to quick-silver. But one considerable advantage both mathematics and mechanics may afford the naturalist, is, by schemes, figures, representations, and models; which greatly assist the imagination to conceive many things, and by that means enable the understanding to judge of them, and deduce new consequences therefrom. 'T wou'd be exceeding difficult, if not impossible, to go through some tedious geometrical demonstrations without the help of a visible scheme; not to mention how hard it is to initiate persons in cosmography and geography without material figures and globes. And how necessary figures and models are in the building of ships, houses, engines, and other structures, every one knows.

* Dr. *Hall* has an excellent contrivance of a diving-bell upon this foundation; wherein he can, with all desirable convenience, descend to any depth of the sea, and there continue for several hours together. See a full description of this engine, and the manner of using it, in the *Philosophical Transactions*, N^o 349. p. 492 and N^o 368. p. 177.

And not only mechanics, mathematics, and anatomy, stand in need of schemes and representations, to give clear conceptions; but many physical things may by the same means receive illustration. And if *Des Cartes* was the first introducer hereof, I think we are obliged to him; for, as *Plato* said, God always acts geometrically; so, in many cases, nature acts mechanically, in animals, plants, and many other bodies; the curious and fine contrivances wherein being well represented to the eye, may greatly assist us in framing just ideas of them.

S E C T. IV.

I COME next to shew, that natural philosophy, by adopting trades, may become very beneficial to mankind; for, first, a knowledge herein will improve the mind of a naturalist; and, secondly, enable him to advance them. 'Tis a prejudice no less pernicious than general, which natural philosophy, and the interest of mankind, receive, that learned and ingenious persons should have been kept strangers to the shops and practices of tradesmen. Most of the phenomena that arise in trade, are a part of natural history; and, therefore, demand the naturalist's care. Nor will it excuse the neglect and contempt of this part of natural history, in men of learning, that it must be learnt from illiterate mechanics; or, that the things it exhibits are works of art, and not of nature. The first plea is so unworthy of a philosopher, as not to deserve an answer; and as for the latter, there is not that difference men, usually, imagine, between the productions of nature and art. Many things called artificial, differ not from the natural, in essence, but efficient: nature performs the greatest share of the business in abundance of trades; for instance, those of the malster, brewer, and baker; in preparing raisins, currans, and other dried fruits; the making of hydromel, vinegar, lime, &c. for, in these, the tradesman does but bring together the respective visible bodies, and leave them to act on each other, according to their several natures. Thus, also, in making glass, the artificer puts sand and ashes together, but the dissolution and union are brought about by the action of the fire thereon; as when it turns wood to ashes, the volatile salt, oil, earth, and phlegm, unite first into smoke, and then into foot. When a pear is grafted on a white-thorn, the fruit it bears will scarce be thought unnatural, tho' produced by a coalition of two different bodies by means of human industry.

But many phenomena in trades are, also, some of the more noble and useful parts of natural history; for they shew us nature in motion, and that too when turn'd out of her course by human power; which is the most instructive state, wherein we can behold her. And, as the observations herof tend, directly, to practice, so may they, also, afford much light to several theories; And these phenomena are, therefore, the fitter to be translated into natural history.

Philosophy beneficial, by being applied to trades.

The phenomena of trades part of natural history, and to be learnt by a philosopher.

The Usefulness of Philosophy.

story, because the persons, in whose hands they lie, usually, know not how to describe their own practices, or the accidents they meet with; so, that if learned men do not register these things, the history of nature will be very defective. And, doubtless, a naturalist would manage these things in such a manner, as to render them far more instructive, and suitable to the design of a natural history, than when related, tho' ever so faithfully, by an illiterate tradesman. Now, certainly, he is unworthy the knowledge of nature, who scorns to converse with the persons from whom it may be best obtain'd. For tradesmen are, commonly, more diligent, in their particular way, than any other experimenters would be, whose livelihood does not depend upon it. And, as necessity is the mother of invention, we, daily, see that this makes the necessitous crafts-man industrious and inventive; putting him upon employing such things as he would, otherwise, never have dreamt of. By this means new properties, uses, and applications of materials, are discover'd; and such as have escaped the observation of others. Again, trades deal, not only in factitious, but natural materials, that are unknown to classical writers, and never used but in the shops; as manganese, zaffora, emery, tripoli, &c. and of both sorts, there are some exceeding useful; thus glass-men and potters employ the two former, and a number of trades the two latter of these particulars. So, among artificial concretes, folders are necessary to gold-smiths, lock-smiths, copper-smiths, braziers, pewterers, tin-men, glaziers, &c. amels to gold-smiths, glass-men, &c. lakes to painters, heralds, &c. and putty to amel-founders, potters, stone-cutters, gold-smiths, glass-grinders, &c. And, even, of those natural things, whereof mention is made in famous authors, many particulars may be learnt in the shops, not otherwise to be met with, as to their differences, characteristics of goodness, and the like. For my own part, I confess, I have learnt more of the kinds, distinctions, properties, and nature of stones, by conversing with two or three masons and stone-cutters, than from *Pliny*, *Aristotle* and his commentators. Tradesmen being unacquainted with books, and the theories and opinions of the schools, examine their materials by mechanical ways, which their own sagacity, or casual experiments affording them, may appear singular, and different from what learned men would have taught them; tho', if they serve their purpose, are new and instructive, and the rather claim a place in natural history. The observations of a tradesman, may not, indeed, when first they make them, be so accurate as those of learned persons; yet, that defect is supplied by a frequent repetition and assiduity; so, that the circumstances he passed over at one time, will obtrude upon him at another, 'till, at length, various phenomena will offer themselves, even to an unattentive eye, which might have escaped a more curious person, in two or three experiments. Tradesmen, moreover, frequently, remark, in the things they deal with, many circumstances unobserved by others, with regard to the nature of the materials, and the operations performable therewith. By goodness and badness, 'tis true, tradesmen commonly mean the fitness, or unfitness of things, to yield a considerable price, in regard of the purposes whereto particular trades employ them; yet these properties usually consist in qualities relating to several other things, and applicable of several other purposes; for some of their *Criteria*, are a difference in the kinds of bodies, of the same denomination.

nation. Thus, from the potter, the pipe-maker, and the glass-man, we may learn a great variety of clays; and no less an one of stones, unobserved by classical writers, from stone-cutters and masons. So from carpenters, joiners, and turners, we may learn, that some kinds of wood, as oak, will endure both wet and dry; that others will last well within doors, but not bear the weather; that some will hold good above ground, but not under water; and, lastly, that others will continue better under water, than in the open air. And as the characteristics inform us of the differences in the kinds of bodies, so may they, likewise, of many qualities therein. Thus from the glass-man and soap-boilers, we learn that some ashes, as those of kali, bean-stalks, &c. abound much more in salt, and make clearer and better glass than others. The malster teaches us the different impressions which barley receives from the fuel wherewith 'tis dry'd. And one whom I know, made great profit by preparing it with wood-fires, in such a manner, that it could not be discovered so cheap fuel had been used therein; for he chose and season'd his wood, so that even the solid parts thereof, when cleft, burnt almost like straw, with a clear flame surprizingly free from smoke. But farther, the naturalist, usually, contenting himself to repeat his experiments, once or twice, at his leisure, has not equal opportunities with the artificer, nor is so much interested to discern what influence the temper of the air, or the season of the year, may have thereon. Thus tanners, we see, gather their bark in the spring, whilst the rising sap abounds therein, because it is not always so good for their purpose, nor parts so easily from the tree. Joiners think wainscot not sufficiently season'd till it be many years old; and, butchers, in several countries, observe, that, tho' a bullock, under four or five years old, be good to eat soon after it is kill'd, yet, if salted, and kept long, 'twill thereby be fretted, and good for little. And, doubtless, 'tis a great advantage the naturalist may derive from trades, that the same things are, successively, practis'd upon for many ages; whence more extensive observations are made thereon, than a philosopher has opportunity for. Thus those who make mortars of *Guaiacum* wood, and design them to be good, will keep the stuff in the house for twenty years, or more, to season, before they use it. And experienced masons say, that some sorts of lime and stone will decay in a few years, whilst others arrive not to their full hardness in thirty or forty; of which I have seen instances. But a naturalist, by frequenting the shops of artificers, may, frequently, learn other things, besides the truth and falsity of what they relate, as to the history of their professions; for he will there observe phenomena, that are neglected by the tradesman, as impertinent, and not tending to his profit; while torturing nature by his art, he discovers to an attentive eye, things not to be met with in books, nor ever dreamt of by authors.

On the other hand, the naturalist, by his knowledge, gain'd from an inspection into trades, as well as his other acquirements, may contribute to the improvement thereof. And this is performable several ways; but, particularly, by increasing the number of trades; by collecting the observations and practices of different arts into a body; and, by suggesting improvements in particular trades. Nor is it absolutely requisite to invent new ones, in order to increase the number of trades; since a revival of those known to the ancients, that seem lost to

*Who may thence
improve them, va-
rious ways.*

The Usefulness of Philosophy.

us, will suffice for this purpose; such are the making of incombustible cloth of *Lapis Amianthus*, the *Tyrian* purple, and *Mosaic* work; with many others mention'd by *Pancirollus*, and his commentator *Salmuth*: of which it might be proper to divulge a catalogue; because, having been once, actually, in being, 'tis possible they may be retrieved in such an inquisitive age as the present. But trades may derive another advantage from the diligent naturalist, by means of several observations made, and different practices used, therein; which the artificers, themselves, want either the curiosity, skill, or opportunities to learn: not to mention the jealousy they have of one another, and their unwillingness to discover their secrets, where they think their interest concern'd; whilst a philosopher finds no shyness, who enquires only to satisfy his curiosity, or with a view to assist them. And, doubtless, were all the known hints, scatter'd thro' the various employments, possess'd by a single person, tho' but of common abilities, he might thence improve most of the particular trades, that are retainers to philosophy. And, perhaps, it were not amiss, if some knowing, and experimenting persons, were appointed by the public for this purpose. Some *French* gardeners have, lately, with good success, applied the way of filtration, used by apothecaries, to water tender plants. They place wicks of cotton, or lists of cloth, in the liquor to be strain'd, so that they hang over the edge of the containing vessel below either surface of the fluid. These ends of the lists, thus hanging over the roots of plants, will uniformly and leisurely supply them with moisture, far better than watering pots. And this method, by a cheap and mechanical contrivance, may be greatly improved. Stone-cutters, who cast figures with plaister of *Paris*, have a way to obtain fine powders, beyond what the common searces would allow of, by stirring the pulverized material well in water, and, soon after, pouring off the turbid liquor, at the bottom whereof an impalpable powder will, in time, settle. Of this method I have made great use in chymistry. And if the first water be suffer'd to remain subsiding, 'till the finer parts begin to descend, a much more subtle powder may be gain'd, than that which artificers usually employ. This method is, likewise, useful to glass-men, potters, the makers of telescopes and microscopes, those who cast metals in sand, and others; particularly in *China*, to the makers of porcellain. The naturalist may, also, render the materials of one trade serviceable to another. The philosopher who has survey'd a great number of arts, and compared them together, may well do this to advantage; since even illiterate mechanics themselves can make use of each others productions. Thus litharge, which is only lead powder'd, and almost vitrified by being blown off the refiners test, not only serves the chymist for *Saccharum Saturni*, and the like medicines; but the comb-makers to dye their horn; being mixed with quick-lime and sharp vinegar; painters, to accelerate the preparations of their fat oils; varnishers, by causing their work to dry soon; and, lastly, it serves to make counterfeit gems; for, by being melted with about a third part of pure white sand, or calcin'd crystals, and then adding a small quantity of mineral concretes, according to the colour intended, sapphires, emeralds, &c. may be imitated; tho' they will come out too ponderous, soft, and dim the method itself; being

not

not the most valuable. *Aqua fortis* is useful to refiners; for herewith they separate silver from gold and copper; to the curious workers in wood, for staining and discolouring thereof; to dyers, in their colours, and even in scarlet; and to other artists, for the colouring of bone and ivory; which they do by steeping them therein, when that is ting'd with copper, or verdigrease, &c. some, also, turn it into *Aqua regia*, by dissolving in it a fourth of it's weight of sal-armoniac, and then stain therewith ivory hafts and boxes, of a fine purple colour, that does not suddenly disclose itself thereon. There are, moreover, book-binders, who throw it on leather, and thereby make fine marble covers for books; and diamond-cutters, who, therewith, free diamonds from metalline powders. 'Tis, farther, of great service it etching copper, or brals-plates; and, lastly, I have caused canes to be stain'd like tortoise-shell, by a mixture hereof, and oil of vitriol, laid on them at several times, over live coals, to cause it to penetrate the deeper; and, afterward, giving them a gloss with a little soft wax and a dry cloth. Nor are these all the uses made of *Aqua fortis*; which, tho' it be aliquor very commonly employ'd, and distilled not only by chymists, but refiners, gold-smiths, &c. yet great overlooks are daily committed in its preparation. But an ingenious acquaintance of mine, by attempting to improve it, has succeeded so far as to make it vastly better than that the refiners usually employ; or than any I have used; and, yet, he affords it for little more than half its common price. Nay, he has not only thus greatly promoted the refiner's trade, but found out a way to recover most of his *Aqua fortis*, after it has been employ'd in the separation of metals, and that too with its virtue increased; for, this fluid may be made, and received in other vessels than are usual. And without dreaming of this chymist's method, I have re-obtain'd that menstruum, exceeding strong, after it had been employ'd upon certain minerals. Lastly, there are other bodies, besides glass and earth, and less brittle than they, that serve for the second distillation of *Aqua fortis*, tho' made, originally, very strong. I might, also, intimate, that, by adding to salt-petre, instead of thrice its weight of clay, or the like, about an eighth, or tenth of it's weight of another substance, I have, even in ordinary furnaces, slowly obtain'd a nitrous spirit, or *Aqua fortis*, at the first distillation, much stronger than what our refiners sell for double *Aqua fortis*. Others have far greater opportunities to inquire into trades, than myself, yet I have, sometimes, gain'd the thanks of eminent artificers for my directions in their respective trades and professions*; which has made me, often wish, that a few ingenious men, who are friends

* Thus M. Homberg instructs us how to gain a larger quantity of the essential oil of vegetables, than is usual in distillation, by the previous addition of mineral acids, as the spirit of salt, &c. thereto; which increase the fermentation, and joining with the oil, render it more liquid, and easy to be raised by heat. This expert chymist advised a perfumer, who before scarce obtain'd an ounce of oil from a hundred weight of roses, to steep his flowers, for fifteen days, in water made sharp with spirit of vitriol, by which means the perfumer, upon distillation, found his quantity of oil increased almost a third. The perfumers keep the structure of the vessel they employ in this distillation as a grand secret. 'Tis a large convenient still, that opens, in a tube, at the top, to receive the water which must often be pour'd upon the roses, to bring over the oil with it; which it does but very slowly, and so requires that its quantity be large. This still, also, opens below, that the flowers, when they will yield no more oil, may

The Usefulness of Philosophy.

friends to experimental philosophy, would enquire into the mysteries of trades, and, afterwards, publish the sum of their observations, tending to the melioration thereof. Some *Italian* authors have wrote treatises of particular professions, as *Antonio Neri* of the art of glass-making, and *Benvenuto Cellini* of sculpture, statuary, and some other arts; which deserve to be made *English*.

And I invite the virtuosi of all nations to contribute their observations towards forming the history of trades, for I esteem that one of the best means to improve experimental philosophy*. Of this I was so far persuaded, that, had not our public calamities prevented me, I should have bound several ingenious youths to particular trades, with a view to receive, afterwards, their respective observations, made by my own direction, and the historical accounts of their professions, when they should have become masters thereof.

There is, likewise, another means, whereby an experimental philosopher may become advantageous to trades, I mean, by surveying the rules and observations already received, and the present reigning practices therein; then remarking the deficiencies and inconveniencies under which they labour, and noting their *Desiderata*; and, lastly, by proposing rational means to remedy the former, and, as far as he is able to supply the latter. By deficiencies and inconveniencies, I don't here mean all that is wanting to such an absolute perfection, as a philosopher might wish for; but what is complain'd of as feasible to be remedied: as for instance, the artificer may be too much confin'd to particular materials, some whereof being either scarce, dear, or ill-condition'd, the naturalist might propose others. Thus, I remember, being once where no good vitriol could be procured, wherewith to make *Aqua fortis*, like that of the *English* refiners; by substituting a far less quantity of burnt alum, in its stead, we made excellent dissolvents of silver, and, perhaps, much better than theirs. And, in the like cases, the naturalist may greatly assist the tradesmen, upon account of his knowledge of a vast variety of bodies, and their operations, at least, by means of his experiments. An ingenious person, whom I knew, upon a general complaint as to the scarcity, and advanced price of oak-bark, contrived a way to prepare leather without any bark at all; and that too, much better than usual in the ordinary way. And, allowing the materials, suggested by a naturalist, be dearer than those in common use, yet they

may be easily, taken out. But the principal contrivance is the figure of the vessel which receives the oil. This is made like an ordinary matras, from the lower part of the belly where, of comes a tube, as from an old-fashion'd crewet and rising to the bottom of the neck of the receiver, it bends outwards, so that, tho' the vessel usually contains but 2 or 3 pints, it conveniently receives, and lets pass, many hundred pints of the rose-water, without any necessity of being changed; for a change would lose the small quantity of the oil obtain'd. The water distill'd, runs thro' the pipe into a second receiver. Now the oil being lighter than the water, it floats upon the surface thereof, and adheres to the

neck of the vessel, as high as the aperture of the little pipe, whilst the water runs from the bottom of the first receiver into the second. *Memoir. de l'Acad. A. 1700. p. 266.*

* The subject of trades, with the manner of preparing all sorts of commodities, in several countries; the proper market for each, the freight they pay, the price they bear at several ports, and, numberless other particulars relating to this head, are fully treated of by M. *Savery*, in a late *French Dictionary of Commerce*, wherein the particular accounts were, by command of the king of *France*, given in from all the public offices, and places of employ in that kingdom.

may,

may, in other respects, be far preferable thereto. Thus, tho' diamond-powder be vastly dearer than emery, yet I, sometimes, order work to be done therewith upon load-stones, as well as gems; for it makes so great dispatch, and the tools employ'd last so much the longer, as greatly to over-balance the cheapness of emery. Common spelter-solder is much cheaper than that made with silver; yet workmen, in many cases, prefer the latter: and I have found this to run, with so moderate a heat, as not much to endanger the melting of the delicate parts of work to be solder'd. Nay, if this silver-solder be well made, as some I can shew, it will solder, even upon ordinary solder itself, with brass and spelter; and so fill up those little cavities that may chance to be left in the first operation; which is not safely performable without a solder more easily fusible than the first made use of.

Tradesmen may, also, be tied down to certain ways of working, when, perhaps, the naturalist may discern, what they do mechanically, may be better accomplish'd philosophically and on the contrary. Gold-smiths, perhaps by the direction of some chymist, boiling their curious silver-work, as spurs, wrought hilts, &c. in salt, alum, and argol, give it such a whiteness and clearness, as it would hardly receive from the brush, pumice-stone, or putty. And the like cleanness, I have learnt from experience, may, immediately, be given to old sullied pieces of good gold, by means of warm *Aqua fortis*. There are some things which, tho' usually done mechanically, may be better perform'd in a philosophical manner; but, at present, we will observe, that much of what is now wrought by manual labour, may, with much more ease and expedition, be committed to engines; which being skilfully contrived, such things may, thereby, be effected, as few would imagine. To pass over several instruments whereon I have, off-hand, play'd various tunes that I never learnt; since we see timber saw'd by wind-mills, files cut by slight instruments, silk-stockings wove by a machine, with abundance of the like artificial inventions, not easily express'd in few words, what handicraft can there be, that is not performable by engines?

But there are deficiencies of another kind; for work may lye long in hand, require too great pains, a large apparatus of instruments, or, some way or other, be more chargeable, troublesome, or laborious than is necessary: and these inconveniencies the experimental philosopher may, in many cases, remedy. I know an inquisitive person who has tann'd as well as the masters of the business, and in half the time that they employ'd. In some places they have an expeditious way of seasoning particular wood for sea-service, and other uses, by baking it in ovens. Our dioptrical glass-grinders supposed they must always use *Venice-glass* for their purpose, 'till some virtuosi considering, that clearness is an inconvenience in an object-glass, taught them to substitute the common green sort, made in *England*; which, in my opinion, and that of some others, is here superior to the other. Several dyers employ our own woad, instead of the *Eastern* indigo, for dying some blues, and other colours, which that grand tincture prepares the cloth to receive. Another sort of deficiency, or inconvenience, may be the want of durableness, as to the being of the thing produced, or the beauty and goodness thereof. Of the former kind is the decay of liquors,

The Usefulness of Philosophy.

quors, the spontaneous cracking of gla's; particularly the fine *Venice* object-glasses of telescopes, will thus flaw, and grow usefess, but chiefly in winter; to prevent which, some of the curious carry them in their pockets. Of the latter kind, is the fading of the bowdy, and water-colours in limning; the rusting of shining arms, and polish'd steel. And here, also, the naturalist may be serviceable. Thus the above-mention'd method of making object-glasses for telescopes, of green gla's, renders them durable in spite of the weather. I have had pieces of artificial crystal, some whereof soon crack'd, and changed their transparency for whiteness; yet another, according to my conjecture, held found for several winters, and never broke, but by accident. The reason of this difference, I suspect to be, that the former had too great a proportion of fixt salt, and the latter a due one. That the scarlet-dye may be greatly improved, in point of fixtness and duration, beyond the common bowdy, I am convinced by a merchant of *Amsterdam*, who rais'd a great estate by dying, and was particularly curious in scarlet. This gentleman shew'd me a piece of thick scarlet cloth that would not stain with vinegar, lixivium, or other liquors that he named; nor when cut, appear pale, or white, in the middle; for the dye penetrated quite thorough: and this he could afford at a reasonable price. And that trades may be, considerably, improv'd by those who do not profess them, we have a remarkable instance in the thing we are speaking of *Cornelius Drebell*, the inventor of the true scarlet-dye, was a mechanic, and a chymist, but so far from a dyer, that he knew nothing of the ordinary reds, 'till, taught them by some merchants; whence, by a sagacious conjecture, he discover'd the scarlet.

And supply the desiderata therein.

I come now to the *Desiderata*, whereby, I mean, those desirable perfections that are difficult, indeed, but not impossible to be obtain'd; and of these several may, sometimes, belong to one profession. 'Tis a *desideratum* with the blacksmith to render iron fusible, by a gentle heat, and yet preserve it hard enough for ordinary uses; with the gla's-man and looking-gla's-maker, to render gla's malleable*; with the clock-maker, to bring the long pendulum to be useful where there are irregular motions; with the brazier and copper-smith, to make malleable solder; with the ship-wright, to build vessels that will sail under water; with the diver, to procure manageable instruments for conveying fresh air to the bottom of the sea, to suffice for respiration, and the burning of lights; with the say-master, to melt, or cupel ores, or metals, immediately, without the use of bellows or furnace; and, lastly, with the carver and joyner, to fashion wood in moulds like plaister of *Paris*, or burnt alabaster. The obtaining of these *Desiderata*, I am sensible, may be thought chymical projects: it is proper, however, to propose them, provided they be not, in themselves, im-

* The high value and scarcity of the ancient graved stones, which, in several respects, are preferable to medals, has occasion'd many attempts to render them more universally known. To this end, the impressions have been taken upon sealing-wax, common sulphur, and coloured gla's, which, as improv'd by M. *Homburg*, has vastly the advantage over the other

two. This gentleman has a way of counterfeiting them to so great a perfection, in gla's of different colours, which he can suit to several stones, that the copies have pass'd upon the virtuosi for originals: so that if gla's were actually malleable, they could hardly be made more perfect. For the method itself, see *Memoir. de l'Academ. A. 1702. p. 250.*

possible,

possible, contradictory to the nature of things, and the principles of reason and philosophy; but proceeding, only, from our want of proper instruments, and previous means, or else some difficulties and inconveniencies that lye in the way, or hinder the prosecution of our designs. This advantage, at least, will, probably, be hence derived, that, tho' sagacious persons should despair of attaining them to perfection, some approaches thereto may be made. Credible witnesses have inform'd us, that in some countries they shoe their horses, without the assistance of a forge, by bringing their iron to such a temper, that they keep shoes ready made, which they can, easily, hammer cold, so as to fit them to any horse: and this being practised in hot climates, is the greater convenience. And, doubtless, by various tempers, iron may be greatly soften'd, and, afterwards, harden'd; since, without antimony, or sulphur, I have melted it in a crucible, and pour'd it out like lead; whereupon it has grown harder than it was originally.

Flexible looking-glasses are made with *Selenites*; and all kinds of hollow glasses may be easily foliated, and turn'd into *Specula*. And, because this may well appear a difficult thing, especially to be done without heat; and, because the usual ways, delivered about it, fall far short of the character given them; I shall here communicate an excellent method of foliating all sorts of figured glasses; the hint whereof I had from an illiterate wandering fellow, in the country, who held his practice, which was confin'd to spherical glasses only, as a great secret. And truly it excelled any I have met with in print. But my mixture is this. Take tin and lead, of each one part; melt them together, and immediately add, of good tin-glass, or bismuth, two parts; carefully skim off the dross; then take the crucible from the fire, and, before the mixture grows cold, add thereto ten parts of clean quick-silver; and having stirr'd them all well together, keep the fluid in a new clean glass. When you go to use it, first purify it, by straining it thro' linen, and gently pour some ounces thereof, into the glass, to be foliated, thro' a narrow paper funnel, reaching almost to the bottom of the glass, to prevent the liquor from flying to the sides. After this, by dextrously inclining the glass every way, endeavour to fasten it to the internal surface; which done, let it rest for some hours; then repeat the same operation, and so continue, at times, till the liquor is, at length, slowly pass'd over, and equally fixt to the whole superficies; which will be discerned by exposing the glass to the eye, between that and the light. Next, gently pour out the superfluous liquor, to be saved for the like purpose; and, lastly, with a cloth, well sprinkled with putty, scraped tripoli, or chalk, carefully cleanse the outside of the glass. This preparation is, also, more easy and safe, than the others I have met with, wherein either arsenic was an ingredient, or the mixture to be used hot. I might here, likewise, add, that by laying a yellow varnish upon the external surfaces of the glasses thus managed, they have appear'd richly gilt, yet so bright, as to serve very well for mirrors*.

* The several ways of grinding, polishing, and thematician C. *Welfus*, in his *Elementa mafoliating* different kinds of glasses, for different *theses universa*. We have, also, an admirable uses, in optics, catoptrics, and dioptrics, are posthumous piece of the great M. *Huygens*, de clearly and fully delivered by that excellent ma- *poliendis vitris*.

The Usefulness of Philosophy.

But to return; that malleable solder is obtainable, I make no great question; and good silver solder is already made an approximation thereto. Submarine navigation has been successfully attempted by *Cornelius Drebell*; and those concern'd in the experiment affirm'd, that, tho' many were in the boat, they breathed freely, and found no inconvenience for want of fresh air; yet the inventor was neither ship-wright, nor sailor. As for the desideratum in diving, I have already said, I knew a person, who, by means of a slight instrument, (the whole whereof remains under water, and has no communication with the air above the surface,) has continued several hours at the bottom of the sea, and removed his engine with him. But *Merfennus* tells us of a much better method, if real, invented and practis'd by one *Baricus*, who was able to continue six hours under water, by help of an almost incredibly small quantity of air, which, at the same time, fed the flame of a lamp at the bottom of the ocean, in a vessel not much bigger than an ordinary lanthorn. There is, also, a method of cupelling, in small quantities, without a furnace, coals, common cupels, or any other vessels. And, by way of approximation, I made a powder, wherewith I have immediately, without a furnace, melted lead-ore, wherein silver is frequently contain'd, into metal, and, perhaps, also consumed some part thereof. And, lastly, I am credibly inform'd, that the way of making embossed works in wood, with moulds, was lately practis'd at the *Hague*, by the secretary of a foreign ambassador; tho', as to the manner wherein it was done, I could not gain the least hint: but if the thing be true, I suspect it must have been perform'd by some menstruum, that greatly softened the wood, and afterwards allow'd it to harden again, as tortoise-shell is moulded; or else by reducing the wood into a powder, and then uniting it into a mass, with a strong, but thin glue; the superfluous moisture whereof being afterwards pressed out. And I once began a trial of this kind, but was hinder'd from prosecuting it, with a curious glue, whereof I, accidentally, gain'd the hint from an ingenious tradesman; which I now prepare, by steeping fine ising-glass, for twenty four hours, in spirit of wine, or common brandy. When the menstruum has open'd and mollified the ising-glass, they must be gently boil'd together, and kept stirring 'till they appear well mixed, and, 'till a drop thereof, suffer'd to cool, will, presently, turn to a strong gelly. Then I strain it, while hot, thro' a clean linen cloth, into a vessel that may be kept close stopp'd. A gentle heat suffices to dissolve this glue into a transparent, and, almost, colourless fluid; which, however, binds so fast, that having, sometimes, by means thereof, join'd together two ordinary square trenchers, and permitted it to dry of itself, the trenchers, that lay one far over another, broke, when a proper force was applied, not where they touched, but elsewhere; so that the force of this glue was greater than that which held together the parts of the wood. Nor will this preparation, by reason of the spirit, corrupt, like other gellies; but the farther advantages hereof I must not now mention: I shall here, only, add, that having imbued, and mix'd up some common saw-dust herewith, slightly straining out, thro' a piece of linen, what was needless, and forming the remainder, with my hand, into a ball; upon drying it leisurely, it became so hard as not to break, but rebound, when thrown against the floor.

From

The Usefulness of Philosophy.

131

From what we have now seen, it appears, that experimental philosophy may as well advance trades, as an inspection into them promotes the interest of that: and the happy influence they may have on each other, is an excellent means to enlarge the empire of mankind. That the due management of trade is of great concern to the public, appears from our numerous statute-laws, at present in force, for it's regulation, wherein the legislature has thought fit to give very particular rules and instructions thereto relating.

I design'd to have added something about varnishes, but, at present, can only say, in the general, that they are an useful and ornamental production, capable of great improvement.

S E C T. V.

LET us now consider how far the knowledge of particular qualities, or the physical uses of things, will enable men to perform, philosophically, what is commonly done by manual operation. And here, methinks, 'tis a notable proof of human industry, as well as a great incitement thereto, that philosophy can supply the want of strength, or art, and the head prevent the drudgery of the hand. The instances I shall give hereof, which are so many trophies of human knowledge, need not be reduced under particular heads; being only produced as proofs, and having no dependance on each other; I shall, therefore, barely set them down as they come to mind.

The king of *Spain* makes such an advantage of the knowledge we are considering, as annually amounted, for some time, to many millions. For in his silver-mines at *Potosi*, in *Peru*, they, formerly, had a very tedious, laborious, and expensive method to separate the silver from the ore, which is now greatly improved and shortened by means of that property of quick-silver, to amalgamate with the nobler metals; first used, in that country, according to *Acosta*, by *Fernandes de Valesco*. Their present method is, accurately, to grind the ore, first pulverized and sifted, with strain'd quick-silver and salt; then to boil them, for five or six days, in pots and furnaces fitted for the purpose; when the mercury imbibes the silver and gold, without touching the baser parts of the ore. The mercury being thus fully saturated, is carefully washed from the adhering filth, and then, by a strong fire, freed from the noble metals; coming over revived into the receiver, and leaving them behind, it easily reducible into masses, and separable the common way. By a process like hereto, some of our gold-smiths also, and refiners, regain, out of their dust and sweepings, the small scatter'd particles of gold and silver, that fly off in their working of them.

It seems to require great skill in statuary, to make a figure that shall, truly, represent the size, shape, and lineaments of a living human face; yet I lately saw this done by a tradesman, in the following manner. The person, whose figure we design'd, was laid upon his back, with a convenient thing placed

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round

round the edges of his face to keep away the hair. Then into each nostril was convey'd a conical piece of stiff paper, about three inches in length, open at both ends, to allow of respiration. These tubes, being anointed with oil, rested with their smaller ends within the nose; while the others were supported by the hand of an assistant. Next, his face was lightly oil'd, and his eyes being kept shut, alabaster fresh calcin'd, in a copper vessel, to its native whiteness, and temper'd to a thinnish consistence with fair water, was by spoonfuls nimbly thrown all over his face, till the matter every where lay near the thickness of an inch. This done, the said matter presently began to grow sensibly hot, and, in about the quarter of an hour, harden'd into a kind of stony concretion; which being gently taken off, and it came away with ease, represented on its concave surface the minutest parts of the original face, even to the single hairs of the eye-brows. In this mould they cast a head of good clay, and therein open the eyes, and, if there be occasion, raise the fore-head, or make other necessary amendments; then anointing this new face with oil, they, as before, make a second mould of calcined alabaster, consisting of two parts, joined lengthwise along the ridge of the nose, and herein they cast, with the same matter, the fore-part of a head, more like the original than ever I saw made by the most expert statuary; and yet this is perform'd with so much ease, that I myself succeeded the first time in attempting it.

Nor need a man be a painter to represent the figure of the leaves of plants; for this may be done by holding one in the smoke of rosin, gum-sandaric, camphire, or a common link; whereby the leaf will acquire a blackness communicable to white paper when pressed thereon, which immediately gives the exact size, shape, and particular ramifications of the fibres thereof. A candle or wax taper will also serve the turn. And this may be of good use to a botanist, or a traveller, when they meet with plants whose figures are worth preserving, and they have no conveniency to draw them.

The art of etching.

The art of etching, also, will furnish us with an instance of the like kind. Copper and silver plates may be hereby enriched with delicate figures, without having recourse to the graver. This is perform'd by drawing a peculiar sort of varnish over the plates and then tracing the figures thereon; for the lines thus made, freeing the plate from varnish in those places, *Aqua fortis*, skilfully temper'd, will there corrode, and leave the remaining varnish'd part untouch'd; and thus afford, under the management of a skilful artist, as curious cuts as the finest graving.

In taking altitudes.

But a knowledge of the physical properties of things, will, moreover, enable us to perform that wherein mathematics, and the instruments it makes use of, appear to be necessary. Thus, suppose a candlestick, that hangs from the top of an high church, be made to swing, a philosopher, who has observ'd, that the vibrations of a pendulum, tho' the arches thereby described be unequal, are, nevertheless, perform'd in equal times, as to sense; and that, when the strings whereby pendulums hang are of unequal lengths, those lengths will be proportionable to the squares of the number of their single vibrations made in the same time; and suppose, farther, this person, provided with a pendulum of any known length, for instance, that of a yard; then, I say, he may easily, without any mathematical

tical instrument, find the height of the church. For the candlestick and short pendulum being both set to swing at the same point of time, if the candlestick, for example, makes 9 vibrations, while the other pendulum makes 54, the squares of these two numbers will be 81 and 2916, and, therefore, because the lengths of the pendulum are proportionable to the squares of the number of their vibrations, perform'd in the same time, divide 2916 by 81, and the quotient, 36, will shew the length of the cord, whereby the candlestick is suspended to be 36 times longer than the short pendulum; which being equal to a yard, the other must be 36 yards. From the knowledge of another physical property of heavy bodies, I have found a way to measure great heights and depths without the common mathematical instruments, and even where they cou'd not be applied. This is also done by means of a pendulum, which must here be very short, and therefore requires an accurate observer. Now, 'tis known, that every heavy body in falling, accelerates its descent, so that the different spaces thro' which it passes, at different times assign'd, are to each other as the squares of the times wherein the respective spaces were described. If then it be learnt, by observation, how far any heavy body descends in a second; the doctrine of proportions will give us, from the time spent by a heavy body in falling, the height from whence it fell. This method of mensuration, we, with care, found agreeable to other observations. And thus, the depth of any well whatever, to the surface of the water, may be known; when quadrants, or the like instruments, cannot be used to discover it. For, if at the same point of time that a stone is let fall into a well, a pendulum that vibrates quarter seconds be let go, and the swings counted till the sound of the stone dashing against the water be heard, the thing is done. Suppose, for instance, that a heavy body descends 12 feet, in the first second of time, from the beginning of its fall; and the pendulum to have completed 6 single vibrations before the sound of the stone be heard; our rule will tell us, that since the times, in this case, are 1 and 6, and the squares of these two numbers, 1 and 36, the stone must have descended at the end of the sixth second, 36 times as far as at the end of the first; the product, therefore, of 36 by 12, being 432, is the perpendicular depth of the well: or thus, more easily, (since, as we formerly observ'd, falling bodies accelerate their descent in a progression of odd numbers from an unit, thus, 1, 3, 5, 7, 9, 11, &c.) the stone descending 12 feet in the first second, will fall 36 in the second, 60 in the third, 84 in the fourth, 108 in the fifth, and 132 in the sixth; all which numbers added together make 432. And by this means the height of precipices, and the depth of volcanos, may be measured; which were otherwise impossible. 'Tis true, in strictness, some small allowance shou'd here be made for the stone's striking before the sound thereof is heard; but unless the space to be measured is very considerable, that may be neglected without much inconvenience; since we know, from observation, that sounds move in air about twelve or thirteen hundred feet in a second. * And an experiment made by a foreign mathematician

* Sir Isaac Newton shews the velocity of that have of late been purposely made to determine sounds *à priori* to be in the air about 1142 feet the matter. See *Newton. Princip.* Ed. 2^d. p. 344; in a second; and to this agree the experiments *Philos. Trans.* N^o. 247. p. 433. &c.

confirms the doctrine here deliver'd; for he found an heavy body to descend 300 feet in about five seconds, that is 12 feet in the first second.*

In splitting thin plates of metal.

To split so thin a piece of metal as an old silver groat, seems to require a fine instrument; but a trifling physical experiment has shewn us an easier way; for if the metal be placed upon the heads of three pins stuck in form of a triangle, and a heap of flower of brimstone be suffer'd to burn out thereon, and you afterwards throw it hard against the floor, the upper part will separate from the lower; which, if the coin were not exceeding thin, still retains its pristine shape. I have observed a pretty circumstance or two in this experiment, the knowledge whereof is apt to be misemploy'd; and the experiment itself, tho' ludicrous, may suggest uncommon speculations to a considering naturalist, and intimate a particular method of preparing silver.

Making marbled paper.

From considering the fine variety of colours in a sheet of marble paper, one wou'd suspect them to be carefully laid on with a pencil, or that the whole was printed off from an engrav'd plate; but 'tis made with the utmost expedition, only by touching the surface of a vessel full of water, whereon the colours lie to be conveniently blended, by a quick and gentle motion of the artificer's hand, without causing them to run too much together. Kircher, as I am inform'd, has deliver'd the process hereof.

Rectifying spirit of wine.

Most distillers wou'd think it impracticable to rectify spirit of wine without distillation; yet I have done this by adding thereto well dry'd salt of tartar, whose property to imbibe the moisture of the air might well give one the hint; especially since oil of tartar *per deliquium* will not mix with dephlegmed spirit. And to hasten this operation, the salt may be ty'd up in a rag, and so plunged in the spirit, when by moving it up and down therein, or raising it above the surface, the water imbibed by the salt will fall, in drops, to the bottom.

The use of cements.

When bodies are so brittle, small, ill shaped, &c. as not to be conveniently held steady by instruments; artificial cements are excellent substitutes for tools. Thus the glass-grinders incorporate pitch and ashes into a stiff paste; wherein, when reduced by heat to a proper degree of softness, the glasses to be ground or polish'd are bedded to what depth, and in what position, is thought necessary: and being by means of the same mixture placed on a proper instrument, there they remain, when the cement is cold, firmly fix'd for operation; after which, the cement being again soften'd by heat, they are easily taken out. The diamond-cutters, who use a very vehement attrition, fasten their stones in a cement made of rosin and brick-dust; and one of the most skilful of them adds some sealing-wax; but plaster of *Paris* is here preferable to brick-dust. And, indeed, so many experiments may be advantageously made by the assistance of cements, that I have been curious in preparing a number of them. Many artificers make use of powder'd emery, in different degrees of fineness, some of which are extremely subtile; but this hard substance is not prepared for their several purposes by different sieves, but by pulverization, ablutions, and proper repeated decantations. And I knew a chymist who by this method prepared much better *Crocus Martis*, which he sold at a more advanced price, than others of his profession.

* All bodies near the surface of the earth fall 16 feet, 1 inch, *English*, in the first second of time. See Dr. Halley's propositions concerning the descent of heavy bodies. *Philos. Transf.* N^o 179. p. 9.

To hew alabaster and marble out of the rock is very expensive and laborious; The obtaining of stone from the quarry. but by the use of gun-powder large portions of both are easily obtainable. The method is, to make a perforation, of the desired length, into the body of the rock, with a tendency upwards, and lodging a convenient quantity of powder in the farther end thereof, the remaining cavity is filled up with rubbish, and well ramm'd in; a little space only being left for a train, whereby fire may be given to the powder, which will thus break the upper part of the rock into several pieces of a manageable size. And by this means, a little varied and improved, some ingenious acquaintance of mine, who were employ'd by the public to raise vast piles, have lately blown up, with a few barrels of powder, many hundreds, or, perhaps, thousands of tuns of common rock.

To fashion glasses for watches, or the like purposes, into a convex or concave figure, they seem to require grinding, or some particular skill in the management; yet I have found, from experience, that a smooth and flat piece of glass, of a competent thickness, being carefully laid upon a shallow concave cylinder of iron, so, that the round edges of both mutually touched each other, the heat of a fire, warily applied, will soften the glass, and suffer it to sink into the form required. This way, 'tis true, will not always exhibit the precise figure one would wish; but when skilfully practised, it succeeds so often, that some ingenious artificers have quitted their usual method of making watch-glasses for this, which is much more cheap and easy. In some parts of *England* may be found various kinds of talc, or *Lapis specularis*, and there are of them very cheap and plentiful, tho' to reduce it to powder by the mortar and sieve is exceeding tedious and laborious; but actual flame will speedily reduce small pieces thereof to a perfectly white calx. And a sagacious acquaintance of mine, thus, also, presently reduced large lumps, by casting them red-hot into cold water. This operation has an affinity to that wherein some chymists granulate masses of gold and silver, by pouring them, strongly melted, from a competent height into cold water, whereupon there happens a dissolution of the parts of the metal; when many small portions thereof fall to the bottom. But the softer metals, as tin, and lead, are better and more expeditiously granulated by the process just mention'd for talc. And by twice or thrice repeating the ignition and extinction, I have immediately brought crystal flints to a fitness for making counterfeit gems.

Figuring of glasses, and reducing talc to powder.

Considerable art seems used to counterfeit fruit in wax, especially when a particular lemon, or orange, &c. is exactly represented: yet this art may be learnt in an hour or two; for, having the fruit to be imitated, 'tis only burying it half way in a clay coffin, the edges whereof, as well as the extant part of the fruit, being oil'd; and nimbly throwing on it temper'd alabaster, or plaister of *Paris*, to a considerable thickness; which, when concreted, and taken off, is a half-mould; wherein the fruit being now placed, with its other end upwards, a second half-mould may be obtain'd, as the former; and when the two are join'd together, a little colour'd wax, melted, and brought to a due heat, being poured thro' a hole, made in any convenient part of the mould, and presently shook every way therein, will, when cold, lively represent the original. And here it might appear an extraordinary piece of art to cause so great a cavity as there will remain in the counterfeit fruit, and to render the representation so perfect with so small

Making images in wax.

small a quantity of wax; whereas, the bare shaking of the mould, together with the expansive force of the included air, applies the wax so close to the whole internal surface, that 'tis thereby form'd into one large film, and seems difficult to be separated without injury, which must ensue, did not nature here again assist the artist, and cause the mixture, when it cools, to shrink from the mould.

Graving of hand-writing.

I know a famous graver who writes but a bad hand, and yet with his tool he can imitate the finest performances of the most celebrated writing-masters. This has appear'd surprizing to virtuosi themselves, that a man, with a stiff iron instrument, shou'd write incomparably fairer upon a tough copper-plate, than with a good pen upon paper. The method itself is kept as a great secret, and I cou'd not learn a curious particular or two; yet by putting questions, and by some trials of my own, I have obtain'd the substance thereof; which is this. The copy to be engraved is wrote by an excellent hand, with a peculiar kind of ink, as black as the common; and the copper-plate, being moderately warm'd, is rubbed over with a certain white varnish, and suffer'd to cool; then the paper being gently moisten'd, that it may readily communicate its ink, the writing is applied to the prepared surface of the plate, and so pass'd thro' a rolling-press; by which means the ink adhering to the varnish, leaves the letters very conspicuous; whence 'tis easy, with a fixed needle, to trace the strokes, thro' the varnish, upon the plate, which being afterwards cleansed, the letters are finished with the graver, and the work printed off in a rolling press, as common cuts.

Taking off written characters, or printed cuts.

I have also taken off written characters without the help of a press, by laying the moisten'd paper smooth upon the varnished copper, and rubbing it hard thereon with a convex piece of glass, or the like; provided the ink be good, and thick laid on. For varnish, here, I have used the purer sort of virgin wax; and for my ink, the fine *Frankford* black, as the painters call it, which was gradually and carefully ground with water, till it obtain'd the consistence of common ink; but no gum is to be added, lest that shou'd hinder its coming off.

There is, likewise, a way whereby printed cuts are so far taken off, that, at least, the outlines, and principal strokes, may be ready copied for graving. If the print be not above a year or two old, the paper need only be well moisten'd with water, as for printing, with the usual ink of cuts; but if it be more ancient, it shou'd be laid to soak all night in water, and afterwards suffer'd to hang in the air till it becomes dry enough for the press. The paper thus prepared, is to be laid with its printed side next the plate, thinly cas'd over with white wax, which is thus to be committed to the rolling press, whereby an impression of the cut will be gain'd.

And copying, at once, a whole page of writing.

But there's one thing that seems more than any, hitherto mention'd, to require immediate manual operation; I mean a method of transcribing, at once, a whole page of writing. Whether this be performable with ease and cheapness enough for common use, is another question; but, that the thing is possible, by physical means, I am convinced from my own experience.

Hitherto such instances have been produced wherein philosophical knowledge may be substituted for manual dexterity, mechanical tools, and mathematical instruments; to these I shall subjoin one, to shew, that a mathematician, and a mechanic, by being acquainted with a slight physical property of obvious bodies, may

may perform what mathematical learning, and mechanical skill, wou'd not otherwise accomplish.

That a massy body, some hundred thousand pounds in weight, shou'd be raised by means of a little water, seems very surprizing; yet this was done at Constantinople, as we learn from *Busbequius*; who tells us, "that a monstrous obelisk, thrown from its pedestal in the city, had remain'd at its length for many ages, till in later times an architect appear'd who, for a certain sum, undertook to set it again upon its base; and having to this end prepared abundance of machines, he therewith raised it within an inch of its due height; when the spectators imagin'd it cou'd not be elevated higher; but he, relying upon his knowledge, of nature, commanded water to be brought him, which being, for several hours, thrown upon the ropes that supported the pillar, they gradually contracted and so set it upon its base, to the great surprize of the vulgar." And to render this the more credible, the like is mention'd by many eminent authors, as having been elsewhere practis'd; and the thing is allowed of by that great master of mechanics, *Galileo*.

Instances wherein a knowledge of nature may improve mechanical skill.

The usual methods of catching fish among us, require pains and skill; but the illiterate *Americans* have preferable ways, from the knowledge of a physical property of a certain wood, wherewith they impregnate the water, and stupify the fish so, that they roll upon the surface, and are easily taken with the hand. And this appears probable from the intoxicating preparations we are here possess'd of, which tho' slight, fall not much short in their effect; and having particularly enquired of a learned physician who came from that country, he assured me it was true, and that he saw the *English* use the same method, by tying a log of this wood, which they call dog-wood, to the stern of their boats. The hair growing on any part of the body, may, without the use of any instrument for that purpose, be very expeditiously taken off, to appearance, by the roots; whence it is again of a much slower growth. This is effected by a property of the natural production call'd *Rusma*. *Bellonius* gives us the method wherein they use this drug in the *East*; but I had made experiments with a parcel of it, before I met with his observations. I mix'd it, in fine powder, with an equal weight of strong pulveriz'd quick-lime, and permitting them to soak for a short space together in a little fair water, they become a soft paste, which I spread thin upon that part of the body I wou'd free from hair; and suffering it to remain on about three minutes, I wipe it off with a linen cloth dip'd in water, and find the hair taken away by the roots, without any discernible inconvenience to the part. Thus I several times repeated the experiment, and more than once perform'd it upon myself.

To measure time exactly, may to some appear scarce practicable without springs, wheels, or the common contrivances; yet so simple a thing as a bullet fix'd to a string will do it. For if that be made to measure a little less than ten inches, from the point of its suspension, to the centre of the bullet, 'twill swing half seconds with less inequality than a good watch; and may, therefore, be of great service in making astronomical and other observations of a short duration, wherein accuracy is required. And by means of a pendulum, a skilful musician of my acquaintance teaches his scholars to keep time in singing. But the best way, in observations, is to make the vibrations as long as possible, and when they begin

to decrease, to give a fresh impulse to the swinging weight, lest by growing short, they shou'd not be so well counted.

By knowing the velocity of sounds in the air, 'tis easy to measure distances, without geometrical instruments, or where they wou'd be useless. The foundation hereof is already deliver'd; for since all sounds, whether great or small, move 1380 feet in a second; if a gun be fired on one side of a river, how inaccessible soever, 'tis but letting fall a short pendulum as soon as I see the flash, and counting the vibrations till I hear the sound, to gain the distance of that gun from the place wherein I stand. Suppose, for instance, the report be perceiv'd two seconds after the light, I conclude the river to be 2760 feet over.

And by this means may be solved a problem that, nakedly proposed, might seem impossible; I mean, without geometrical instruments, to measure, in a dark night, the remote distance of one ship under sail from another. For, supposing one of them to fire two or three of her guns, a pendulum may be set a going at the first, taken as a signal; and its vibrations counted that pass between the flash and report of the second. And, by the way, I have thought, that if the velocity of echoes, which are only reflected sounds, cou'd be well determin'd, sailors might, sometimes, in the dark make useful estimates by means thereof, as to their distance from the coast, or considerable rocks. For tho' they cannot justly conclude upon discharging a gun, how near they are to the shoar, because some parts thereof may lie less remote than those which reflect the echo; yet were that found to follow immediately after the original report, there's reason to suspect the land as near as the pendulum shews the echoing-place to be.*

S E C T. VI.

A sound kind very ignorant in natural things.

BUT we may venture to assert, there is scarce a production in nature, the Uses whereof to human life are hitherto thoroughly understood. This proposition being very intelligible, needs no explanation; but as it is an ungrateful

* Sounds are now commonly used, as the most exact means for determining the distance of one place from another; and the most accurate surveys are made by the help of them, since their velocity has been precisely determined. And upon this foot Mr. Whiston, some time since, proposed a new survey of England. 'Tis still more remarkable, that he and Mr. Ditton, improving upon this hint, by adding light to sound, and joining the assistance of the eye to that of the ear, advanced a method of discovering the longitude at sea. Their design was, that from a certain number of stationary hulks, or ships riding at anchor in convenient parts of the sea, at due distances from each other, large fire-shells shou'd, at 12 a clock, every night, be thrown from mortars, to the perpendicular height of a mile, or more, and there afford a large blaze of white light. For, if from a ship out at sea the ascent of this ball of fire be observ'd, the sailors will thence know the difference of time between the meridian of their ship, and that meridian in the plain whereof the fire-ball ascends; so that the point of the compass from whence the light came being observed, and the place where the explosion was made found mark'd on the sea-chart, the longitude at sea must thence be discover'd. They also proposed other methods for finding the same, as from observing the time that passes between the first seeing the light, and hearing the sound of the mortar; or from the angle wherein the ball appears at its utmost height. But all of them, tho' very ingenious and good in the theory, are defective in the practice; being exceeding troublesome, and yet precarious. These inconveniencies Mr. Whiston is now attempting to remedy by means of the dipping-needle.

paradox;

paradox, it requires a full demonstration; because it cannot be admitted without such a confession of our ignorance as must tacitly accuse us of laziness. However, we may say, with *Seneca*, a greater knowledge and command of nature wou'd have been gain'd, had it not been presumed we were already arrived to a much more considerable degree than, indeed, we are, in comparison of what remains behind obtainable. I shall, therefore, offer some considerations to rouse our curiosity, by shewing how defective it has been, and how much of nature continues undiscover'd to exercise and reward our industry. It must be remember'd, that I here suppose the usefulness of nature's works to mankind chiefly depends upon the knowledge we have of their properties; and, consequently, that the more we learn of these, the more uses we receive therefrom; so that whatever assists us to discover things which, probably, may prove useful, is a physical use thereof, tho' in itself not immediately practical.

I observe, in the first place, that very few of nature's works have been sufficiently consider'd, even as to those qualities that properly belong to them. There's a kind of *terra incognita* in every natural body, reserv'd for the discovery of futurity. For there are various artificial means of finding out the properties of things, by chymistry, optics, statics, &c. which require such skill, industry, and instruments in their application, that few have the curiosity and ability to examine materials in all these several methods; yet unless this be done, various properties thereof, some of which are, probably, capable of useful applications, are likely to remain undiscover'd, as might be easily shewn by an induction of particulars. But many things, doubtless, must continue unknown in the abstruser productions of nature, when even the most obvious and familiar objects hide abundance from us. To instance in our own bodies, wherewith we are highly concern'd to be acquainted; how many discoveries have been made in the present age that remain'd unthought of for above two thousand years? The happy success of *Harvey*, *Astellius*, *Pecquet*, *Bartholine*, and *Wirsungius*, are remarkable instances hereof. In bodies so familiar as those of eggs and chickens, tho' *Aristotle*, many ages since, was solicitous about their history; yet so little, till within these few years, was known concerning them, that it grew a hot dispute, whether the chick were formed of the white, or the yolk; when our excellent *Harvey* shew'd, as I have also observed, that it proceeds from neither of them, nor even the treddle; but that speck which appears in the coat of the yolk. *Kepler*, is said to have been the first who told the world so obvious a thing as, that the parts of snow are of an hexagonal figure, in a discourse wrote on that subject. However, I find, *Olaus Magnus* makes mention of it; and I myself have frequently observ'd the same thing; especially about the beginning of the season; for that is not its constant figure; but 'tis surprizing, the discovery shou'd not be made before the present age. As common a liquor as vinegar has been for many ages, yet, that it often abounds with shoals of living creatures, which thro' a microscope appear like eels, was a discovery which seem'd so new but a few years ago, that when I observed it, to some virtuosi in *England*, as a phenomenon to be seen with the naked eye, they thought me deceiv'd, till their own eyes fully assured them of the contrary. That the milky way shou'd for two thousand years pass for a meteor is not strange, considering the minuteness of the stars

The works of nature imperfectly consider'd, even in their peculiar qualities.

that compose it; nor do I, for the same reason, wonder, that the predecessors of *Galileo* reckon'd only seven planets; nor suspected *Venus* to represent the same phases with the moon: these instances however, serve to shew, that many attributes of bodies are scarcely discoverable without artificial helps. But what may not mankind overlook, when the sun itself, the most conspicuous body in the universe, has vast dark spaces, perhaps bigger than *Asia* or *Europe*, frequently generated and destroy'd upon his surface; whereof even the astronomers took no notice till the excellent *Galileo*, and the industrious *Scheiner*? In the year 1660, *April* 27, about 8 a clock in the morning, I my self observed a spot in the lower limb of the sun, a little towards the south of its equator, which was enter'd about $\frac{1}{3}$ of the diameter of the sun itself, being about $\frac{1}{60}$ in its shortest diameter, of that of the sun, and its longest about $\frac{1}{4}$ of the same. It disappear'd upon *May* 9, in the morning, tho' we saw it the day before at about the same distance from its western limb, a little south of its equator; tho' it first appear'd from the east limb, a little south also of its equator. It seem'd to move faster in the middle of the sun, than towards the limb. It was a very dark spot, almost quadrangular, and enclosed round with a dusky cloud. We first observed this very same spot, for figure, colour, and size, to be re-enter'd the sun *May* 25, when it appear'd to be in a part of the same line it had formerly traced, and was enter'd about $\frac{4}{11}$ of its diameter at 7 a clock in the evening. At the same time there appear'd another spot, which was just enter'd not above $\frac{1}{11}$ part of the sun's diameter. It appear'd longest towards the north and south; and several small clouds seem'd to be dispers'd about it.* The discovery of these spots, indeed, was made by means of telescopes, instruments unknown to the ancients; yet had mens curiosity been rais'd to that height the nobleness of the object deserv'd, part thereof, at least, might have been observed without them; for I find by an *Italian* letter of *Galileo*, that some of his acquaintance, after he had roused their curiosity, describ'd spots therein with their naked eyes.

Things have different relations to one another in different places, seasons, &c.

It might here be remark'd, that one reason why men are ignorant in the uses of such things wherewith they seem well acquainted, may be, that the difference of climates and places occasion new relations between them, and thereby endow them with unsuspected qualities. I shall not here enumerate the different properties of bodies commonly referr'd to the same species, whether of plants, animals, &c. in almost every country; as, that spiders are not venomous in *Ireland*; and, that *Irish* wood, in general, if the tradition be true, is an enemy to poisonous creatures: I will only add two instances; the one to manifest what different climates may do; the other to shew the unexpected influence of different places, perhaps, in the same climate. The inhabitants of hot regions, where it never freezes, who deride the relations of what happens in the colder, wou'd

* From abundance of observations more lately made of these spots, and publish'd in the *Philosophical Transactions*, the *French Memoirs*, the *Acta Eruditorum*, &c. it appears that they are nearer to the sun than the planet, *Mercury*; that yet they are not actually on the sun's surface, but at some distance from it; that new ones frequently

appear and disappear, and are, therefore, probably form'd of the sun's exhalations, or are its clouds. Hence it shou'd seem that the sun has an atmosphere, like that of the earth, wherein, since these spots or clouds fall back again to the sun, several changes must necessarily happen in that luminary, as well as in its atmosphere.

never

never imagine that water cou'd be broken in a mortar like a dry body, be transported in open carriages, kept all the year round in that form, and, lastly, communicate an intense coldness to other water in the summer. And the less inquisitive among ourselves can scarce believe that water will serve for high-ways, in travelling, the marching of armies, the training of artillery, and for a field of battle; yet in the more northern countries all this is practis'd upon the ice in the winter season.

The second instance, is the declination of the magnetic needle from the true north and south points; with the variation of the same. For, altho' the loadstone has been long admired, and since its happy application to navigation, generally known, and peculiarly studied; yet that the needle does not in some places point directly, perhaps not by many degrees, to the pole, as it will in others, is no ancient observation, being ascribed to *Sebastian Cabot*. And, according to our famous *Gilbert*, he must have lived since then who first remark'd that strange and considerable alteration of the unexpected phenomenon, its declination in the same place, towards the east or west, in process of time; the truth whereof I cou'd confirm by observations of my own, compared with those of modern authors. And as the same bodies may have different qualities and uses in different places, so may they also, if examin'd, and employ'd at different times, seasons, or peculiar periods, wherein they undergo some signal changes. But these are not obvious to every eye, as when fruit grows ripe, or wine turns to vinegar; but such as require skill and curiosity in the observer. Thus, while common urine is fresh, the volatile and pungent salts are so clogged with other particles therein, that near nine parts in ten must usually be evaporated before they will rise; and afterwards a considerable heat given to force up the last. Now, tho' the tradesmen who deal in urine commonly overlook the difference; yet if the urine be barely kept for six or seven weeks, the saline and noble parts will in that time have so extricated themselves, that a very gentle heat will raise them first, and leave that phlegm behind which in the former case preceded.

That the *Thames* water, when carried long voyages, and into hot climates, will have a very offensive scent, the common putrefaction of stagnant water may persuade us; yet 'tis found, if that be kept long enough, tho' in the same vessel, and a hotter climate, it will at length grow sweet and potable again. And this I have not from vulgar tradition, but receiv'd, by enquiry, from two very inquisitive persons, upon their own knowledge; one whereof had particularly observ'd it in sailing between *Europe* and *Africa*; and the other in going and returning from *America*. And I the rather mention this, because several other waters have, as I am inform'd, the faculty of recovering after putrefaction, as well as that of the *Thames*; whereto 'tis usually supposed peculiar. And having had the curiosity to try how the rougher kind of water, that will not bear soap, might be remedied; an industrious person, whom I employ'd, assured me he had met with pump-waters, that, barely by standing a few days, wou'd gain this property.

Coriander-seeds, when fresh gather'd, are observed to have such an acrimony, that some ancient physicians account them venomous; and dispensatories usually order them to be corrected with vinegar, or the like; but the more ac-

curate

The Usefulness of Philosophy.

curate observers tell us, that this seed, in a competent time, loses, of itself, this offensive quality. And the like in both respects is observed by some eminent apothecaries as to the roots of aron.

'Tis allow'd, that vegetables, however managed, unless first reduced to foot, will afford no dry volatile salt, like that of animal substances; yet, by discoursing lately with a very ingenious person, as also by some experiments made to examine distill'd liquors, I was satisfied there are various vegetables growing common in *England*, which, gather'd, and laid together, at a certain season, and distill'd at a particular juncture, will yield a volatile spirit that in its scent, taste, and various effects, as turning syrup of violets green, hissing with acid spirits, &c. resembles the volatile spirits and salts of animal substances: and, what appears surprizing in this great change, the secret whereof I wish I durst communicate, it is effected without any addition.

Nor are vegetable and animal substances only thus alterable in their texture; but even mineral bodies themselves. 'Tis a complaint in chymistry, that tho' we are taught to make the salt of distill'd vitriol by immediately taking the *Caput mortuum* thereof, freed from the oil by a violent fire, and extracting all its saline parts by repeated affusions of water; yet this means will not obtain the salt. But I found, by enquiring of those who distil large quantities of oil of vitriol, that if the *Caput mortuum* be suffer'd to lie a considerable time in the air, 'twill be so impregnated with new saline particles, as to be worth a second distillation. And, as we formerly mention'd, there are quarries of solid and useful stone, some whereof has been employ'd about stately buildings, that I have seen, whose property, as we have also heard of other kinds, is, that being dug at a particular season of the year, it proves thus good and durable; but if employ'd at a wrong time, makes but wretched structures; as has been found by sad experience.

Time and place are, indeed, two of the principal, but not the only things whose variations may discover unheeded properties in natural bodies; even the slightest circumstances may afford new uses in solid and lasting materials. Optical glass-grinders have complain'd to me that their convex glasses will frequently prove veiny; and thereby render the labour bestow'd upon them almost useless; because they are unable to discover these blemishes by the most careful examination, till a considerable time be spent in the work; and even then they continue invisible while the glass is held at an ordinary distance from the eye; but upon removing it some feet therefrom, those defects become apparent: so serviceable may an encrease of distance be where one wou'd least expect it.

Bodies must be
consider'd mathe-
matically before
their properties can
be known.

The change of posture may seem a smaller circumstance than the change of distance; yet Dr. *Gilbert* has observed, and I have found it true, that perpendicular iron rods, as the bars of a window, by long standing in that position, acquire magnetic poles; so that the needle of a dial, for instance, applied to the lower part of such a bar, will have its southern end attracted; whereas, the upper extremity of the said bar will seem to repel that, and attract the northern. And here I cannot but observe, that men will scarce ever be able to know all the properties and uses even of familiar bodies, till they shall have been mathematically consider'd; for there are many things thereto belonging, which, probably, a naturalist, how curious soever he may be, will never otherwise discover. Various instances,

instances, which prove this assertion, have been already produced; however, the thing is of so great importance for naturalists to be convinced of, that I shall again inculcate it upon them with a few more examples. Since the first ages of the world men must, sometimes, have beheld swinging bodies; yet till *Galileo* no one took notice that their vibrations, whether great or small, were perform'd in equal times. This discovery required a mathematical eye; and some of the uses of it we have seen already.

That, water running out at a hole near the bottom of a vessel describes a parabolic line, or one that nearly resembles it; and, that, in the like experiments there's a determinate proportion assignable between the perpendicular height of the water, and the diameter of the hole; whence the quantity that will issue out thereat in a given time, with its velocity, may be computed; was not, that I know of, observ'd before *Galileo* and *Mersennus* attempted to adjust this matter.

As frequent as are the occasions we have to take notice of air, water, and glass; our modern masters in optics have made great discoveries as to the different refractions of the rays of light in those several mediums, with other particulars, unregarded by such as are not skill'd in that science. 'Twas from a geometrical contemplation of the drops of dew upon the grass and leaves, with the colours the rising sun usually paints therein, that the great *Des Cartes* rais'd a neat hypothesis to account for the phenomena of the rain-bow. For he found, that in one particular angle made at the spectator's eye, by a ray of light proceeding from a certain part of the drop, and the imaginary strait line reaching from the eye to the sun's centre, the appearance of red was exhibited; in another, that of yellow; in a third, that of blue, &c. and in some, no colour at all. 'Till this time the world was ignorant of such considerable properties of spherical diaphanous bodies illumin'd by the sun. Thus also, tho' wood and timber must have been daily broke, by weights; yet till *Galileo* applied geometry to this subject, the resistance of solid bodies in breaking, by means of their own weight, or that of others, seems nor to have been suspected reducible to calculation. And a virtuoso of my acquaintance, can, from a musical instrument, whereof he is master, observe a property of metals not dreamt of by chymists. He hereby finds, that equal wires of different metals, will, upon due tension, yield sounds different in sharpness by determinate musical notes, or the divisions thereof. It were easy to add various other remarks, made by *Mersennus* and *Galileo*, as to the force of guns encreasing proportionably to their length, but decreasing when they come beyond a particular standard; the parabolic line wherein bullets shot out of a gun are said to move; and the like mathematical properties of things, which geometricians, astronomers, engineers, &c. have already observed. But I shall only subjoin one instance more to prevent our imagining that the most familiar objects, wherein the fewest properties seem discoverable, have been sufficiently consider'd. What phenomenon in nature occurs more frequently than the falling of heavy bodies? yet not a soul, that we know of, once made a fair attempt to determine their acquired velocity till *Galileo* reduced it to the proportion formerly mention'd; wherein most of the succeeding mathematicians have acquiesced. In a word, till geometry, mechanics, optics, and the like sciences, be more generally and skillfully applied to philosophy, many properties and uses of natural things, must, doubtless, remain unknown.

The Usefulness of Philosophy.

Even the most obvious qualities, and their uses, may be overlook'd.

And as we have hitherto observed of bodies, so will I venture to add of qualities, and various other things in nature, that even the most obvious may have attributes and uses which learned men overlook. That black bodies, for instance, are sooner heated by the sun than white ones, or those of any light colour, is, perhaps, but very little taken notice of; yet this is demonstrable in many particulars, as may easily be try'd in a black glove, and a white one; or in two eggs, one whereof is black'd. Cold is one of the most familiar qualities we deal with; and tho' little is apt to be expected therefrom, it will perform the office of heat in spirit of wine, and present us with inflammable spirit from beer, and other liquors smaller than wine.* And, to pass by *Paracelsus's* process of making the essence of wine by freezing all the phlegm; those who have failed into the frigid zone assure us, from repeated experiments, that not only wine, but beer, by a congelation of their more aqueous parts, will separate therefrom a strong, hot, spirituous liquor. Even in our own temperate climate some odd separations may be made by cold; as, particularly, of a liquor from oil, much finer, and more spirituous than the rest. I know an eminent artificer who held it as a great secret, to resort, in hard frosts, to large jars of oil, and there take out the fine thin fluid from the cracks in the congeal'd part; this being much better than the other to preserve things from rust; and for this purpose, also, some watch-makers, who were made acquainted with its virtue, highly esteem'd it. But it were tedious to insist on all the instances produceable of applications that may be made of colours, sound, levity, elasticity, fermentation, and putrefaction; and endless to prosecute what might be afforded by more general and active states and faculties of bodies. For, not only motion, and rest, fluidity, and firmness, gravity, and the like, have a more universal influence on things than even philosophers observe; but the less general properties of matter, reckon'd among particular qualities, as respective gravity and heat, may be so diffusive and applicable to so many different purposes, that 'tis a question whether all the uses of that particular degree of heat in fire will be discover'd while the world endures. I must not here omit, that many more qualities in the most known bodies wou'd, probably be remark'd, did we not want such a measure of particular curiosity, for of the general I don't here speak, as might be justly expected; such a curiosity, I mean, as to the things wherewith we familiarly converse, as we could scarce want but thro' laziness or prejudice; whence we presume to take for granted what we ought to try and examine. Thus, that falling bodies descend the quicker in proportion to their weight, has been believ'd in the schools since the days of *Aristotle*, and prevented the truth from being taken notice of; namely, that all bodies, how different soever in bulk and weight, descend with equal velocity; till inquisitive men lately found it by experiments.

That water by being froze contracts into a less compass, is still the opinion both of the vulgar and generality of learned men; yet the quite contrary is evident from experience: and the bubbles that are usually found in ice, with its floating upon water, might make a considering man suspect it. The air we breathe, has, for many ages, been supposed a body endow'd with positive levity; but if

* *Dr. Beal* has observ'd, that a vehement and he seems to think it might be applied to other degree of cold will serve to distil spirit of wine; purposes. See *Philos. Trans.* N^o 56. p. 1140.

men had the curiosity to examin, they wou'd find it heavy: even that common way of condensing it in a blown bladder confirms this assertion; for, allowing the included air not to be in its natural state, but crowded together; yet if the particles whereof it consists be actually light, they ought to weigh lighter when the bladder is filled with them. However, there are other methods of making the experiment clear of this objection.

Large sounds are commonly thought to move swifter than small ones: 'tis true, indeed, they don't both reach to the same distance; but, 'tis known from late observations, that they go with equal velocity. That a load-stone, which by immediate contact takes up iron, shou'd have this power greatly encreased, when capped, or by a piece of a steel, of a proper shape, interposing between the body and it, seems strange; and what the ancients, who admired its attractive virtue, never vouchsafed to try: but he must be a novice in magnetics who can doubt hereof, since *Gilbert* wrote. Magnetism is so large a field, that it wou'd be tedious to enumerate all the truths I cou'd therein deliver; and these, too, are such as few wou'd think probable enough to deserve a trial. Unslaked lime is generally believ'd, both by the vulgar and the learned, to grow hot by *Antiperistasis*, if cold water be poured thereon; and, contrariwise, when the water is heated; and some have even used it as an argument in the proof of other things: but a few experiments might easily disabuse them; for by the affusion of various liquors, actually warm, I have made lime slake, at least with its usual violence; and, on the contrary, I have preserved other parcels of it, for a long time, unslaked in liquors actually cold, whereto it has imparted no sensible heat.

The quality of the instances here alledged renders it needless to encrease their number, since a greater inducement can hardly be desired for us to expect the discovery of new properties in the works of nature, were our curiosity but duly employ'd in making experiments, than, that many have been found which seem'd so unlikely, that 'twas thought in vain to search for them. It might here be added, that bodies of the same denomination, whence men usually expect only the same operations and uses, may yet have peculiar ones, and sometimes different from each other. We may farther consider, that the faculties and qualities of things being, generally, only certain relations either to each other, or to men; when that whereto they relate is better understood, many of them, wherewith we are already tolerably acquainted, may be found to have useful properties hitherto unobserved. By the qualities of things being relative, I mean, they have so great a dependance on the structure or constitutions of other bodies disposed or indisposed to be acted upon thereby, that, did no such objects exist, those qualities in the bodies said to be endow'd therewith, wou'd be only dispositions to produce such effects, if convenient objects were not wanting. Thus, for example, the faculty of a key, as to its opening or shutting, depends upon the

*New properties of
bodies arise from
discovering their
new relations.*

The Usefulness of Philosophy.

correspondent lock; but if no such thing as that existed, the key wou'd be a bare piece of iron, of a determinate size and shape. So, many a thing that seems useless to us, whilst consider'd only with regard to itself, may hereafter prove highly serviceable, when other bodies, whereon 'tis peculiarly fitted to act, shall come to be discover'd. Tho' iron was known and employ'd from the earliest ages; tho' its uses are numerous; and tho' it had pass'd thro' the hands of chymists, physicians, mineralists, &c. and been employ'd to numberless different purposes, for some thousands of years; yet it conceal'd its noblest and most useful property, that of pointing north and south, when touched with a load-stone, till within these three or four ages.

After all the vain attempts of chymists to fix the fluid body of quicksilver, which, tho' the sharpest frost fails to congeal it, the vapor of melted lead will sometimes render consistent, tough, and hard. Upon what variety of bodies has vinegar been employ'd; and how many purposes had it served, especially by means of its acidity, before it was put to the dissolving of crude or calcined lead; when it exhibited a sweetness beyond that of sugar?

Spirit of urine has long been known to chymists, and seems likely to prove an excellent menstruum for several bodies; but after having been employ'd to dissolve various solids, 'twas improbable it shou'd coagulate with so thin, light, and volatile a fluid as spirit of wine; yet if these two liquors be sufficiently pure, they afford, when mix'd, a strange and perfectly white concretion. The spirituous parts of urine, likewise, without being separated from the others, have a still more extraordinary faculty when duly applied to musk. Of this I was inform'd by a scholar, who, living in *China*, had often seen musk made. 'Tis there the practice, he told me, either before or after this drug is put into the cod, or bags, prepared of the animal's skin, to hang it in a necessary-house, but not low enough to touch the filth; that so it may receive the fetid exhalations of the place, for some days, whereby its less active scent is fetched out and heighten'd. The same person, having carried a parcel hereof from that country to some remoter parts of the *Indies*, found the voyage had greatly decay'd its strength, which he restor'd by tying it up in a bladder wherein many small holes were made with a needle, and laying it in such a place as was just mention'd. An eminent physician of *Rome*, also, tells it as a secret, practis'd among the perfumers of that city, to recover the scent of decay'd musk, by keeping it wrapp'd up in linen well moisten'd with rank urine. *Gypsum* is put to several uses by the stone-cutters, those who mould plaister or wax, and other artificers; but one wou'd not suspect it shou'd also be applied as a remedy to canary; yet, that large quantities of it are mixed therewith, is not only a tradition among the dealers in that wine, but comes to me confirm'd by an eminent wine-merchant who lived many years in the *Canaries*: and a curious eye-witness assur'd me, that about *Malaga*, a large quantity of it is tun'd up with the juice of the grapes.

is a noble metal, and has been very long known and employ'd; yet one very fine use thereof was discover'd only since the art of annealing upon glass came to be practis'd. For, prepared silver, or even the crude metal, being here burnt on a glass plate, will tinge it of a fine yellow or golden colour. There are also several mineral earths, and other coarse fossils, of use in this art; which, by means of fire, impart transparent colours to glass, and sometimes very different from those of the bodies themselves. Hence it appears, that we can scarce ever be sure we know the several uses obtainable from the bodies we converse with; since upon the invention of a new art or trade, whereof a vast variety will, perhaps, hereafter be discover'd, many unsuspected applications of things may chance to be made. Lixivia, prepared of common ashes, have long been very familiarly used to wash linen; but this seems very remote from the property they have, when strong, to turn syrup of violets, or the bruised flowers of that plant, to a perfect green, in an instant. Red is an obvious, and, generally, a pleasing colour; but so offensive to the eyes of a turkey-cock, that it causes great signs of offence in that fowl. Oak-leaves, whereof no extraordinary property is usually observ'd, being, when fresh gather'd, immersed in mineral chalybeate waters, will turn them blue, or black, according to the proportion and strength of the two ingredients. It does not seem probable that charcoal shou'd be a proper thing wherewith to cleanse and brighten particular metals, or to promote a clearness, and give a gloss to some transparent bodies; but mathematical-instrument-makers, gravers, &c. find it excellent to polish their brass and copper plates, after they have been rubbed clean with powder'd pumice-stone. The more curious, will, for this purpose, burn it a second time, and quench it in a convenient fluid. Plates of horn are also polishable the same way; and to those of metal, a gloss may be afterwards given with tripoly. We may here observe, that not only the nature of the body to be work'd on, but some particular circumstances relating to it, may also contribute to the effects of such experiments as we have mention'd. Thus it seems improbable, that water, being apt to run out wherever it finds a vent, shou'd of itself become the fittest instrument for closing leaky wooden vessels; which it does by plumping up and swelling the adjacent parts. And upon the like effect depends that odd experiment, so much talk'd of by eminent *English* sailors, of immediately stopping a small leak in a ship by thrusting thereinto a piece of salt beef; for the sea water, being fresher than the brine that is imbibed, penetrates into the compact body of the beef, opens the salts, and causes it to swell so as to bear strongly against the edges of the broken planks, and thereby hinder the water from flowing in.

Let us next consider, that a body in association may have new uses, and some of them quite different from what it had alone; I mean, two or more materials being conjoin'd, may be qualified to act on a third, upon account of fresh properties thence accruing to the composition. As tin is flexible, and yields but a dead sound, who

B dies in conjunction may have new uses.

The Usefulness of Philosophy.

wou'd dream, that a considerable use of it shou'd be to make a less yielding and better sounding metal more strong and sonorous? yet bell-metal is principally compos'd of tin and copper. In the preparation of common ink, the infusion or decoction of galls is either yellowish or reddish; and the solution of vitriol, as that concrete partakes more of iron or copper, will be green or blue; yet 'tis the mixture of these two that gives the blackness. That oil shou'd be a principal ingredient in a tenacious cement, and the only liquid one employ'd, cou'd not well be suspected; yet, not to mention my own trials as to this particular, an ingenious man, well vers'd in water-works, assures me, the best method he knows to close and mend the pipes of subterraneous aqueducts, is with dry tobacco-pipe clay, pulverized, mix'd with a large quantity of short flocks, and carefully beat up, with linseed oil, into a stiff paste. And before I learnt this, having occasion to try some experiments relating to cements, an ancient artificer, employ'd to keep in order the conduits that brought water to *London*, also told me, in exchange for a lute I taught him, that oil was a chief, and the only liquid thing in the cement he us'd about that important work. Lead is one of the most opaque and flexible bodies in nature; one wou'd not, therefore, expect it shou'd make three parts in four of a transparent and exceeding brittle mixture; yet this is easily obtain'd by chymistry in the *Vitrum Saturni*, which I myself have often made of calcined lead, and powder'd flint, or sand. Who wou'd expect, that the fix'd salt of kali, which is of a strong and fiery taste, easily soluble in water, or even the moisture of the air, shou'd be one of the two principal ingredients of a substance perfectly insipid, and undissolvable even in the most corrosive and penetrating menstrua? yet such a substance is glass. I confess, I doubted whether there was any large quantity of alkalizate salt in glass, till enquiring of an ingenious master of a glass-house, he told me, they obtain'd many pounds in an hundred above the weight of the sand employ'd to make it; and that the alkali did not only seem to promote the fusion of the sand, but largely contribute to compose the glass. And that bodies in conjunction are applicable to new uses, and, perhaps, to some quite different from those they had when separate, may be shewn by many examples. Thus, oil, tallow, and the like unctuous materials, which of themselves spot and defile apparel; will, when skilfully join'd with others, tho' but a lixiviate salt and fair water, greatly contribute to make soap, whereby such blemishes are easily removed. Salt of tartar is a fix'd body, and has a fixing quality; yet when skilfully associated with the most fixed body, gold, dissolved in *Aqua regia*, the gold precipitated by this incombustible salt, becomes so exceeding volatile, that by a less degree of heat than wou'd kindle any known body in nature, 'twill give a report vastly more violent than that of gun-powder. And, what is no less strange, the inflammable body of sulphur being mixed herewith, will, tho' fired, hinder this very inflammable gold from lighting; and thereby turn it into a medicine, said to be diaphoretic;

retic ; which, by means of a crucible, I have long continued in the fire without loss. That the proportion, also, of ingredients may greatly vary the effects and uses of mixtures, we have a remarkable instance in the mineral call'd by the glass-men *Manganese* ; which, tho' of itself it be coarse and dark, and when added to the materials of glass in too large a proportion, makes that black sort which is sold in the shops ; yet a moderate quantity of it is used to turn glass red, and a smaller to render it clear and transparent. Again, a body, by different preparation or management, may be fitted for new, and, perhaps, unsuspected purposes : for the qualities of materials generally depending upon the texture of the small parts whereof they consist, the ways of ordering them, whether by an addition, detraction, or transportation of their component corpuscles, so as to produce any remarkable change in their texture, bid fair to introduce new properties and uses. Thus, mere tradesmen, by varying the visible shape of certain portions of iron, and connecting some of them after a particular manner, have converted it to various purposes ; as we see in the shops of iron-mongers, clock-makers, &c. And to give a more physical instance, in the same metal, what an immediate alteration is made in the invisible texture thereof by fire ? The same bar of iron, by means of that and water, is hardened, and brought to a condition fit for drills, springs, &c. to make which, different degrees of temper are required in the metal. But to leave such cases where no new ingredient is either added to, or taken from the body to be alter'd, and come to those wherein the addition seems to have but an inconsiderable share in the change. Paper, besides its common uses, may be made into frames for pictures, fine emboss'd work, and curious moveables ; by steeping a convenient quantity of the best white sort, for two or three days, in water, till it becomes very soft ; then reducing it, by the mortar, and hot water, into a thin pulp, to be laid on a sieve to drain off its superfluous moisture ; and afterwards putting it into warm water, wherein a considerable quantity of fish-glue, or common size, has been dissolv'd ; for being now with a sponge pressed into moulds to acquire the figure design'd, it may, when taken out, be strengthen'd, as occasion requires, with plaister, or moisten'd chalk, and when leisurely dried, painted, or overlaid. Another uncommon use of paper, is to stop up cracks or fissures in wooden instruments and vessels to hold water ; for in this case it will forcibly dilate and fill the place wherein 'tis lodged. The sugar-cane was known in many countries and ages, as to the sweetness of its juice, wherein sugar never seems to have been made therewith, for want of knowing how to coagulate it into so durable a substance. Tobacco, also, was a noted plant in the *West-Indies*, but suffer'd yearly to perish, like other herbs, till modern industry found the way to cure it, and at length improve it, merely by force of skill, to a condition fit for sale and transportation over all the globe. The leaves of indigo, likewise, which wou'd otherwise perish like those of common shrubs, have by the sole way of managing

Varying with the different proportions of their ingredients, and ways of management.

them,

them; which too consists in deduction rather than addition; long been made to afford a lasting pigment; which is one of the most staple commodities of the *East-Indies*. I might add the great uses we make of madder, woad, and many other perishable plants, by the methods wherein they are order'd; but these are not comparable to the advantages formerly mention'd of the plant *Mandiocha*, which, tho' actually poisonous, yields, by an easy management of the savage *Americans*, both excellent bread and drink. The shreds and parings of leather, parchment, or vellum, only by being long boil'd in fair water, and strain'd, make size; which is very useful in several trades: and, to instance in an easy experiment, fine red stands, and hanging shelves, are coloured with ground vermillion, temper'd herewith; being, when dry, laid over with common varnish. It seems scarce credible, that ivory shou'd, without any addition, afford the most perfect black yet known; which is obtainable by burning it a while in a close vessel, or committing it in several folds of wet paper, to hot coals and ashes. By the way, this ivory-black is so excellent in its kind, that scarce any thing serves so well for foils to the noblest gems and diamonds: and a jeweller, whom I employ'd, confess'd, he thus used it when his work was design'd to be extraordinary. That the strait-gut of an ox shou'd, by the management of illiterate tradesmen, become transparent, and, tho' reduc'd to a thinness exceeding that of paper, continue incredibly firm and tough, seems strange; but 'tis a practice with gold-beaters to include thin plates of gold between these fine membranes, and thereon to bestow many strong blows with a vast, heavy hammer, made on purpose, so as to attenuate and dilate the metal, whilst the skins continue firm and unbroken; as I have with wonder observ'd. The instances here produced are, generally, such as nature alone, or assisted by illiterate persons, affords us. It cannot, therefore, be question'd, that more skilful management may produce great changes in bodies, and fit them for new uses; especially, if chymistry, mechanics, and mathematics, shou'd contribute their assistance. That mathematical skill may teach men to order natural things so as to obtain other uses from them than are commonly thought of, may appear from several particulars. By barely giving to a piece of glass a prismatic figure, that body will beautifully represent all the colours of the rain-bow in an instant. A concave foliated glass, or metalline speculum, will burn vehemently by reflection; and a convex glass, or even water in the same figure, will do the like by refraction. A concave spherical vial, indeed, will not of itself do this, tho' it transmit the rays; but it will when filled with water. And, perhaps, ice itself, that is free from bubbles, and reduced to a spherical figure, will serve for the same purpose. But this effect wou'd be far greater, if two concave glasses of like shape, equal size, and truly ground, were by a frame join'd close at their edges, so that the cavity between the inside of the glasses and the frame may be filled with water; for, thus the whole will serve as a double convex glass; some whereof I have seen, which by

this contrivance may be made much larger than the common sort, that consist of a single piece of glass. Glass-stopples are made by giving them an almost conical figure, and a surface, fitted by grinding to touch closely with the inside of the neck of the bottle; yet this simple mechanical contrivance is so excellent, that neither *Aqua fortis*, or the most subtle spirits, can possibly escape where 'tis used. And by this means I remember spirit of sal-armoniac preserv'd exceeding fresh and strong, for seven years.

Chymists, we see, can from some wild fruits, or the lees of liquors, draw an inflammable spirit which may serve, in many cases, for that of wine; from the dryest solid woods, or bones of animals, force large quantities of spirit, oil, and phlegm; and from the opaque body of lead, mix'd with sand, and a few grains, perhaps, of metalline pigment, some of them can, in two or three hours, make various artificial stones that shall pleasingly imitate rubies, emeralds, &c. What improbable effects are sometimes producible by a slight chymical preparation, appears from the *Bolonian stone*; which, tho' its appearance promise nothing of the kind, acquires by calcination a strange property of shining in the dark, soon after having been exposed to the sun. And, truly, very trivial circumstances in the management of a body, will, sometimes, produce considerable and unlikely effects. 'Tis commonly observ'd, that salt dissolved in water strongly prevents the coagulation thereof; yet the same salt externally applied to water, greatly contributes, with snow or ice, to make it freeze artificially; and is so necessary hereto, that they, without the assistance hereof, will not usually in our climate readily produce any ice; as I have purposely tried. There is a certain powder, which by the proportion and mixture of nitre, its chief ingredient, with the rest, obtains so odd a texture, that if exposed in a crucible to the fire, as usual, 'twou'd blow up with great violence; yet if instead of kindling it from the bottom upwards, that be done from the top downwards, no danger ensues; but it makes a powerful flux for the reduction of metalline powders, wherewith 'tis mix'd, into a body. But, lastly, the generality of effects being not producible by one unassisted production either of nature or art, but by the concurrence of several; whoever is ignorant of the nature or properties of all the other bodies wherewith the subject of an experiment either is or may be usefully join'd or employ'd, cannot discern all the effects of that experiment. And a body that seems useless to the main and ultimate end, may greatly contribute in some intermediate or subordinate part of the operation. Thus, tho' spirit of wine will scarce ever extract a red tincture from the flowers of sulphur; yet these being open'd and flux'd together, with an equal weight of salt of tartar, I have found them, in a few minutes, yield, with a gentle heat, a blood-red solution or tincture in that spirit well rectified; which being afterwards freed from the superfluous menstruum, affords a much finer balsam than that prepared with oil of turpentine. 'Tis usually thought impossible to gild iron with water-gold, that is by
means

The Usefulness of Philosophy.

means of quick-silver; yet I know a very ingenious tradesman who cou'd perform it by the mediation of another body, before the application of the amalgam. His way was, first to lay the iron, to be gilt, over with copper, by help of some distill'd liquors temper'd with other ingredients; wherein the metal being very carefully immerfed, the experiment succeeded; otherwise the iron wou'd be spoil'd. But to prevent this inconvenience, he cas'd it, when bright, with copper, by frequently immersing it in a strong solution of good vitriol, that contain'd copper, in warm water; suffering it each time to dry of itself, till copper enough remain'd thereon. And by this certain, cheap, and easy way, iron may be gilt, as copper, with the amalgam of gold, and mercury. It must here be observed, that, tho' the several parts of an experiment may, in most cases, be purely physical or chymical, for instance; yet it might frequently be more advantageously contrived, that while one part is physical, the others shou'd be perform'd by particular arts, as statics, mechanics, hydrostatics, &c. so that by a concurrence of different parts of knowledge to the same operation, many things will, questionless, be perform'd which have not hitherto been attempted or dreamt of. For whoever is skill'd only in one of these parts of learning, must needs be cramped in his attempts, and confin'd to operate by such means and instruments as lie within his reach; which must, therefore, often prove defective. Thus not only handicraft-trades do many of them mutually assist each other, but the nobler arts sometimes stand in need of the meaner, as well as of one another. The masters of catoptrics, 'tis true, are well acquainted with the properties of the various kinds of *specula*; but in order to procure them in perfection, they must have recourse to the chymist or the founder; and for the polish, to the smith, stone-cutter, &c. To make a pair of organs requires skill in the theory of music, a knowledge in wood as to its conditions, and the ways of seasoning it, in turnery, joinery, and the effects and mixture of metals, with the method of casting them to form sonorous pipes of the due figure, and with the proper qualifications. Bells, and other musical instruments, might afford us many more examples to this purpose; but I proceed to those of another kind. Tho' the nature of nitre and brimstone be ever so attentively consider'd apart, that will never enable any one to make the more considerable uses of either, till they are skilfully join'd together, with charcoal, in gun-powder; which, consisting of these three different ingredients, neither being of itself sufficient to produce the effect of the composition, but all jointly contributing thereto, affords a remarkable instance of what I wou'd shew. Another considerable use of sulphur will remain unknown to him who is unacquainted with some properties of common oil and calcin'd alabaster. For by means hereof moulds may be made wherein to cast off the impression of embossed-work on metals; which, tho' it appear strange, is easily practis'd. The method is this. About the work, whose impression is desired, having made a ledge of clay, and carefully oil'd the whole; brimstone melted in a close-cover'd

cover'd vessel, to prevent its firing, is, whilst hot, poured gently upon the embossed metal, in a large quantity, that so the mould may be the stronger: about the edge of this mould make a border of clay, as before, and lightly oil the internal surface of both; then pour gradually into it, to the thickness of about the quarter of an inch, a mixture made up, with calcin'd alabaster and water, to the consistence of stiff honey; which soon growing hard, may be taken out of the mould. And thus I have, sometimes in a few minutes, easily obtain'd the image of a coin, medal, or landscape. And, as I lately hinted, particular bodies may often conduce to the principal effect of an operation, by performing some subordinate or intermediate offices remote from the ultimate effect. Thus, *Aqua fortis*, tho' it eagerly corrodes both silver and brass; contrary to all probability, greatly contributes to the silvering of brass, in the following manner, which is more applauded than known. First, this menstruum excellently serves to cleanse embossed work, or pieces of metal whose unequal surfaces prevent the application of tripoly, or the common powders for cleaning of brass; for such bodies being lightly wash'd over therewith, and immediately thrown into fair water, the foulness will be thus fretted off, and the work not disfigured: and on the scouring of the metal the success of the experiment greatly depends. Secondly, fine silver must be dissolved, by the same menstruum, in a broad bottom'd vessel of glass or glaz'd earth; and the *Aqua fortis* being afterwards evaporated, water is to be poured upon the remaining calx, in a sufficient quantity, to dissolve it. This water, also, must be evaporated, and the like operation repeated as often as there's occasion; the fire being encreased towards the latter end, so as to leave a perfectly dry and white calx, which will thus be tolerably freed from the fetid fretting spirits of the *Aqua fortis*. Of this calx take one part, and an equal measure, not weight, of common salt, and of the crystals of tartar, and mix them together into a fine powder; then having first plunged the scoured brass into fair water, rub some of the powder upon it with your wet fingers, till the cavities of its surface be sufficiently filled therewith. Lastly, wash the metal well in fair water, and give it a gloss by rubbing it hard with a dry cloth. This washing, tho' it be expeditious, cheap, and requires no quicksilver, may be made to last some years, or is easily renewable when it begins to wear.

To proceed; we ought not to conclude, that a particular use is unobtainable from things, because the like is had from others supposed of a quite different nature; for among various instruments employ'd to the same purpose, some may exceedingly differ as to other qualities, yet agree in that which is requisite to perform the office required. Thus, tho' rosin, and sal-armoniac, for instance, differ in colour, scent, taste, weight, and degree of hardness; tho' the one be a vegetable production, the other a composition of several salts; this easily dissolvable in water, that not so but in oil; with numberless other disagreements between them; yet either of them singly is applicable to the tinning of

brass or copper vessels. So, likewise, there appears no affinity between water, sand, and tin; yet they equally serve for hour-glasses; tho' the ancients, 'tis said, employ'd only the former for that purpose.

'Tis no less certain, that we shou'd not imagine, because a certain body is useful on some occasions, it cannot therefore be converted to other purposes, that seem of a different or opposite nature. For this I suppose possible, first, from the different constitution of the body work'd upon by the same agent: thus the heat of the sun at once melts wax, and hardens clay; spirit of vinegar, that, digested on filings of copper, acquires an abominable taste, gains a great degree of sweetness from standing upon those of lead; and, lastly, spirit of salt, that dissolves iron and copper, like *Aqua fortis*, precipitates silver dissolved by that menstruum. Secondly, a parcel of matter, usually consider'd as the same body, may contain parts of very different natures; whence its operations will be diversified. Thus, when some unripe minerals are calcin'd with nitre, its inflammable parts burn up and dissipate in smoke what is volatile and combustible of the minerals; but by virtue of the remaining alkali of the nitre, several other parts of the mineral are thereby render'd far more fix'd, and capable of enduring the fire, than they were originally. So sulphur contains some parts that make it more inflammable than either nitre or oil, yet abounds with acid and vitriolic particles, that strongly resist the flame in several other bodies; and the fire thereof, besides its common effect seen in matches, acts, from its acidity, in a different capacity upon some metals, especially iron, and also upon red-rose leaves, which are turn'd white by its fumes. 'Twere easy, if necessary, to alledge many other instances of the different actions of different parts of bodies, and also to produce other cases where-in things are convertible to uncommon uses; but those already offer'd may suffice. I have not here meddled with the medicinal uses of things, tho' these wou'd furnish me with numerous instances to my present purpose; since abundance of bodies, both natural and artificial, used as remedies, have various and apparently contrary effects. The different properties of rhubarb both to purge and bind, and of spirit of wine to heat or cool, as internally or externally used, were formerly mention'd. Mercury, taken crude, has sometimes proved innocent or effectual in case of worms; but when rais'd into fumes and receiv'd into the body, too often occasions dangerous commotions. But the various and different operations of antimony, according to the temper and disposition of the patient, and preparation of the mineral, may, alone, suffice to shew, that the medicinal uses of things might greatly have swelled the number of my instances, had I thought fit to have dwelt thereon. And tho' what I have all along insisted upon, almost wholly relates to the neglected uses of particular natural bodies, it must not be imagin'd there are no advantages to be had from other natural things which have hitherto been unknown or overlook'd. By natural things, I mean, the different states of matter, as to rarity and density, fluidity and firmness, putrefaction

and fermentation, with the more active qualities of heat, cold, gravity, &c. the laws of local motion among the parts of matter, and the present fabric of the universe, especially that of the terrestrial globe and its effluvia.

S E C T. VII.

MANY observations and experiments, tho' communicated for true Why attempts to repeat experiments fail of success. by ingenious authors, or unsuspected eye-witnesses, or, perhaps, recommended by our own experience, may, upon farther trial, fail our expectations: and this unhappiness will sometimes befall even those who are exquisitely skilled in the manner of making trials of different kinds; and that upon account of the materials employ'd, or some mistake in their management, not easily to be discern'd. These materials may be distinguish'd into natural and factitious, genuine and adulterate, simple and compound, &c. but we forbear to insist on such divisions, and content ourselves to throw what we have to say on this subject into a few comprehensive observations.

And, first, several experiments fail of success because they are at one time tried with genuine materials, and at another with sophisticated ones, First, because the materials differ in point of genuineness. of different qualities; for, sophisticated bodies, may, by foreign mixture, or a deceitful way of preparation, produce such effects, as had they been genuine they wou'd not have done. It's scarce imaginable to one not very well vers'd in drugs and simples, how generally they are adulterated by the fraudulent avarice of the seller; especially when the sophistication is very gainful. It has lately been much complain'd of by some cultivators of clover-grass, that from a great quantity of the seed, no grass has been produced, tho' neither the soil nor the sower were in fault. This, some analogical observations lead me to suspect, arises from the want of heart in that superannuated seed sometimes sold in the shops. And one of the most eminent and sober chymists of *Amsterdam*, who was also an *Indian* merchant, assured me, that most of the cinnamon, and cloves, brought into *Europe*, is first, in the *Indies*, defrauded of its aromatic parts. And to give a more apposite instance to our purpose; how conspicuous soever little animals, like eels, are in some vinegar, yet there are many parcels of that fluid wherein 'tis in vain to seek for them.

Sublimate is commonly sophisticated with arsenic; and what different effects such sublimate may have, from that which is faithfully prepared, not only upon metals, but upon human bodies, when made into *Mercurius dulcis*, those who are acquainted with the noxious qualities of arsenic will readily imagine. And, indeed, as for chymical preparations, there are scarce any vulgarly sold in shops to be rely'd on. For my part, I have so often met with chymical preparations insincere, that I dare

scarce trust any, either in the administration of physic, or so much as in any considerable experiment, except what my own furnaces afford, or those of persons of known skill and integrity. Having occasion to use some spirit of salt, whereof I was unprovided, I sent for it to a chymist, who himself prepared it; and tho' I gave him his own price for it, yet at the first rectification, even in a retort, a single pound of it afforded six ounces of phlegm; and being farther rectified, in a high body, and a gentle heat, the remaining spirit let go a scarce credible quantity of the like nauseous liquor; and after all this separation of phlegm, it was not pure enough for what we intended. Complaining of this to an excellent chymist of my acquaintance, he sent for some of the same kind of spirit to a very eminent distiller of it, who passes for a very honest man; but this, besides its weakness, was sophisticated either with spirit of nitre, or *Aqua fortis*; which betray'd itself by its peculiar odious smell; whilst spirit of salt, genuinely prepared, is commonly of a greenish colour, and has often a grateful scent. 'Tis not enough, in many cases, to separate the aqueous parts by dephlegmation, as many chymists content themselves to do; but some liquors contain also an unsuspected quantity of small corpuscles of an earthy nature, which, associated with the saline ones, clog or blunt them, and thereby weaken their activity. Such liquors, therefore, to be well depurated, must be distill'd off with a slow fire, that the dry feces may be left behind in the bottom of the glass. We have sometimes taken of the better sort of spirit of salt, and having carefully dephlegm'd it, remov'd it into glasses less tall, and gently abstracting the whole spirit, there remain'd in the bottom and neck of the retort, whence 'twas distill'd, a surprizingly great quantity of a certain dry stiptical substance, for the most part of a yellowish colour. And the spirit of salt, after this second depuration, was so chang'd, that it seem'd to be a much nobler liquor than before. But what different effects wou'd be produc'd by two such different liquors as true spirit of salt, and that which is mix'd with the spirit of nitre; the former whereof will precipitate silver, when the latter has dissolv'd it?

In their species.

Secondly, even when the materials, employ'd about experiments, are genuine, there may be a considerable difference betwixt substances of the same kind and name, and which pass, without suspicion, for bodies of perfectly the same nature. For, tho' antimony, quick-silver, gold, copper, &c. are severally, without scruple, suppos'd of the same nature, and perfectly similar to themselves; yet there is a manifest difference in them, as well as in vegetables or animals of the same species. Thus, as the white-rose, the red, and the damask, differ greatly from one another, tho' all three are roses; and as the sour and sweet orange are very different betwixt themselves, and both of them from the China-orange, tho' all are oranges; and as the hound, the grey-hound, the spaniel, the tumbler, the mastiff, &c. are very differently qualified, tho' all of them are dogs; so the different parcels of antimony to be met with in mines, have different qualities, tho' all of them are antimonial concretes.

concretes. There is, indeed, this difference betwixt the variety to be observ'd in vegetables and animals, and that in minerals, that the former is more obvious to the eye, and betrays itself by something remarkable either in the size of the creatures of the same kind, or in some peculiar shape or colour; whereas, minerals appearing to the eye either perfectly similar, as metals, or at least to consist of but two or three distinct ingredients, as cinnabar, and some other mineral concretions; the diversity to be found betwixt minerals of the same denomination, is hardly discernible till experience discovers it. The womb of a mineral is not always, like that of an animal, a place secured from the intrusion of all bodies not of kin to that included in it; but a mineral, being generated in the bowels of the earth, lies open and exposed to other mineral juices or steams of what different nature soever; so that I have observ'd marcasites and metals, marcasites and stones, salt and sulphur, &c. blended in the same lump of matter. And I have sometimes found, in a great mass of one sort of mineral, small parcels of another of a quite different kind, perfectly enclos'd in the substance of the former. And these intruding bodies being coagulated, and, perhaps, ripen'd together with the former by length of time, are not easily separable or distinguishable when first dug out of the ground, much less after they are melted. For the miner, aiming only to obtain a quantity of such a metal, or other mineral, as is vendible under a determinate name, has no design, nor, perhaps, skill, to make nice separations of the heterogeneous bodies to be met with in his ore; but melts as much of them as he possibly can promiscuously together, and then sells the product to the merchant, or the chymist, for that metal or mineral whose outward form and properties it has; tho' the metal for which it passes be but the predominant ingredient of the lump. So that many other minerals may, in small quantities, here lie conceal'd, and upon occasion be discover'd by exquisite separations, or manifest themselves by unexpected operations when they meet with bodies fit to act on.

An ingenious goldsmith of my acquaintance, complain'd to me, that frequently buying parcels of gold, brought in small pieces, or sandy corpuscles, from *Guinea*; tho' he found it upon all trials to be true gold, yet it was so very pale, that few but expert goldsmiths wou'd meddle with it; so that he was sometimes reduc'd to melt it with very high colour'd gold, or to heighten its tincture with that of copper. And Monsieur *Flacourt*, governor of the *French* plantation in *Madagascar*, speaking, in his history of that island, of the metals there, says, "the inhabitants have a gold of a different nature from that in *Europe*;" and adds, "that this gold is pale, and not worth above fifty shillings an ounce;" and farther, "that the negroes affirm there are many mines of it in the country, where it was formerly dug; that there are three sorts thereof, differing in fineness from each other;" and, what is most remarkable, "that *Malaccassan* gold, as they call it, is almost as easily melted as lead;"

lead;" whilst the fine gold we deal with, requires vehement fires and borax to facilitate its fusion.

Upon visiting some mines of lead, and other metals, I found a great difference, discernible even to the eye, betwixt the several ores; for instance, I observ'd some lead-ore so like steel, that the workmen call it steel-ore; which being of a more difficult fusion than ordinary, they mix with other ore, by them call'd firm-ore, when they commit it to the furnace. I likewise took notice of an ore, which, for its aptness to vitrify, and serve the potters to glaze their vessels, the miners call pottern-ore, and sell it dearer than other ore, from which it visibly differs, and, as the workmen affirm, in many other qualities; yet all these ores, after fusion, pass indifferently under the name and notion of lead. No wonder, then, that curious enquirers find a great variation herein. I lately caus'd some lead-ore to be tried, which being the most promising I ever saw, made me suppose it might contain some considerable quantity of silver; but tho' it prov'd so rich in lead as to yield after the rate of seventy pound in the hundred, yet one of the most expert artists in *Europe* cou'd not extract one grain of silver out of it; tho' the lead of very many mines, being skilfully treated, will leave a proportion of pure silver upon the test. This quantity of silver, indeed, is not considerable enough to make such mines as yield that lead pass for silver-mines; yet such mines as are look'd upon but as lead-mines by the metallist, will appear to be mix'd ones to the naturalist; who may meet with several experiments wherein so little silver will make their lead operate differently from that of ores wholly destitute of silver.

The same differences might, probably, be found in the ores of other metals, if they were purposely and skilfully examined. A very experienced person in these affairs, was lately very desirous I shou'd procure him some tin-ore; alledging, that he had met with a sort, which, after a long digestion in lixivate liquors, afforded him a very considerable proportion of the richer metals; so that having a large quantity of that ore, and finding the experiment on it to succeed constantly, he promis'd himself an estate from it; but when that stock of ore was spent, the next that he procur'd, tho' carefully managed as the former, was wholly unprofitable. And having once bought a parcel of block-tin, as the tradesmen call that which is most pure and unwrought, I was desirous to try if I cou'd not make a menstruum to dissolve it, as *Aqua fortis* dissolves silver, and *Aqua regia* gold; because chymists complain, that tho' they have a menstruum or two that will dissolve crude tin, yet they want one to keep it dissolv'd; and not, like *Aqua fortis*, let it fall into a calx. Such a liquor being obtain'd, we evaporated a solution of that tin; and setting it to shoot, found, to our wonder, that the crystals it afforded were not at all like any kind of vitriol, but, broad, flat, and exceeding thin, like those of silver: examining them also by the tongue, we found not that they had any such taste as the calx of tin, made in spirit of vinegar; but such an excessive bitterness as may be met with in the crystals of silver, made with

Aqua

Aqua fortis. Finding this farther resemblance betwixt the salts of these two metals, that both of them presently dyed the nails and skin with a black that cou'd not soon be wash'd off; we shou'd have suspected, that the menstruum had exalted this metal into an affinity with silver, had we not afterwards prosecuted the same trial with the same menstruum, and another parcel of block-tin, and found, that tho' this metal was bought very soon after the other, and at the same place, the former success proceeded from our having lighted upon a lump of tin that was of a peculiar nature.

I remember, also, that a friend of mine found, in his own land, a parcel of ore, which seem'd to me to be copper-ore; and, indeed, it did, after fusion, yield a very good copper: but the persons, to whom he committed the examination of the mine, being very inquisitive, and extraordinary skilful, found in that ore, besides the copper, a considerable quantity of silver; and in that silver, a considerable proportion of gold.

That great chymist *Basil Valentine*, speaking of antimony, tells us, "there are several kinds of it, and especially two; the one more mercurial, and of a golden property, manifest by the shining streaks it abounds with; the other more full of sulphur, but wanting the golden nature that enriches the former;" and adds, "there is such a different goodness betwixt the several sorts of this drug, as betwixt the several sorts of flesh or fish; which, tho' agreeing in name and general nature, exceedingly differ in point of excellence." And, indeed, I have found a visible difference betwixt the several sorts of antimony. An excellent chymist shew'd me a parcel of antimony as a rarity, upon account of the variously colour'd sulphur wherewith it was conspicuously enrich'd; and soon after employ'd it to make butter of antimony: but tho' he was very expert in that kind of distillation, yet instead of the liquor he expected, upon the approach of a gentle fire, he found the neck and body of his retort lined with an antimonial cinnabar; at which being surpriz'd, he withdrew his fire till he had acquainted me with the accident; and I saw the cinnabar in the unbroken retort, tho' it seldom rises till after the butter of antimony is come over, and the remaining matter be urged with a vehement fire. And to the undiscern'd difference of antimonies we may, sometimes, ascribe that contingency frequently observ'd in making antimonial cinnabar.

And, perhaps, it is from some diversity either in antimonies or irons, that eminent chymists have often fail'd in their endeavours to make the starry regulus of them: whence many artists vainly imagine a certain respect to times and constellations requisite to produce it. An industrious acquaintance of ours, working on antimony of a peculiar nature, and making a regulus of it, alone, in the common way, found, to his surprize, his regulus adorned with a more conspicuous star than ever I had seen in stellate regulusses of antimony and iron; yet I dare not be confident that this depended wholly upon the peculiar nature of that antimony, because my own laboratory has, since that time, afforded me several

The Usefulness of Philosophy.

veral such parcels of regulus ; which, tho' made of antimony that seem'd more rich than ordinary in sulphur ; yet as it did not constantly afford a starry regulus, tho' order'd by the same person, and as near as possible after the same manner, it does not clearly appear whether the different event of the several trials proceeded from the peculiar nature of this or that antimony, or from some odd and scarce discoverable circumstance in the management of the operation.

A considerable difference is observable in several other minerals, as well as antimony. I was lately presented with a piece of mineral which seem'd to be an ordinary worthless marcasite ; yet a *Dutch* merchant, a skilful mineralist, its possessor, was very industrious to procure a large quantity thereof ; having in some of it found a considerable proportion of pure gold. And the gentleman, whose copper-ore I formerly mention'd, digging for more of it, lately found a quantity of red earth, which by knowing mineralists was guess'd to be only bole ; but being melted with *Regulus Martis stellatus*, by a skilful trier of metals, it many times recompens'd the examiner's curiosity, by affording him many grains of fine gold. And tho' I cannot say, whether this gold proceeded from the bole, or the regulus ; it may serve for an instance, that some bodies, which pass, without dispute, for minerals of a precise nature, may have lurking in them substances of quite another kind ; which may manifest themselves in some particular experiments, tho' not in others.

Talc, usually employ'd in cosmetics, is of so very difficult calcination, that eminent chymists have look'd on all calces of talcs as counterfeit. And, indeed, we have not calcined *Venetian* talc, without allowing a length of time, and a violent heat to the operation. But among many sorts of *English* talc, there is one which a moderate fire will, in less than an hour, reduce to a snow-white calx : of which I have seen a parcel. And I lately met with another sort of *English* talc, which I cou'd suddenly calcine, even with the flame of a candle. And a friend of mine assures me, that out of a *German* talc he met with, he, by digesting it in a strong solution of alkaline spirits, separated a considerable quantity of good gold ; and might have made it a very gainful experiment, if all the talc growing in the same place had been equally rich with that. The like has been affirm'd to me by a gentleman of eminence, who, from a certain talc, which he had out of *Norway*, once drew a tolerable proportion of very fine gold : and tho' some have been pleas'd to laugh at all attempts of separating any thing from any kind of talc, yet some parcels of that mineral afford a rich tincture, for ought I know, of a golden nature. For I have met with a kind of darkish colour'd talc, which, when cast only into *Aqua regis*, the menstruum manifestly work'd upon it, and dissolv'd its colour'd parts in such plenty, that the filter'd solution pass'd, without suspicion, among many eminent naturalists for a fair solution of gold. *Paracelsus* reckons four kinds of talc ; red, white, black, and yellow, and, perhaps, each of these colours comprizes several kinds of the mineral ; and, therefore, after having mention'd a great variety

variety of marcasites, stones, and other minerals, he adds, "there lie many more in the bowels of the earth, which are unknown both to me and others, but may in tract of time be discover'd."

'Tis vulgarly known, that there is a great difference between vitriols of the same metal; and as for those vitriol-stones, whereof we in *England* make our vitriol; I have seen at our chief copperas-works so great a variety of them, that I could scarce believe the workmen, when they affirm'd them to be all copperas-stones: and I think it very likely, that some of them contain other mineral substances besides vitriol; and possibly the saline parts of those stones, upon their solution by the rain, may work on other substances formerly coagulated with them, and thereby communicate to some parcels of the vitriol, qualities not essential to the nature of that substance, nor ordinarily belonging to it.

That there is, also, a difference betwixt those bodies which pass under the name of common salt, must be obvious to every chymist, who hath made accurate trials upon that substance. And for those concretes that pass for salt-petre, there is, probably, no small disparity among them, besides the obvious difference betwixt good *English* nitre, and that which is brought from *Barbary*. Those who use both good *European* and good *East-Indian* salt-petre, assure me, they find a difference betwixt them, and give the preference to the latter: and indeed I have often thought I discern'd a considerable difference in the operations of several kinds of salt-petre, even after purification. And, probably that sort of it, which an ingenious man of my acquaintance sometimes makes, near *London*, chiefly out of sea-salt, has some different qualities from that which is drawn in the common way from earth. Indeed, salt-petre being but a kind of *sal terra*, generated in parcels of the earth, very differently qualified, may, probably, receive several qualities from the soil wherein it grows; though these qualities lie conceal'd and unsuspected, under the common external appearance of nitre. A very ingenious gentleman assured me, that one of the most eminent of our *London* physicians, had an excellent secret, to employ in some of his choice remedies, that peculiar salt-petre which he drew out of the earth, dug up in church-yards. A gentleman also assures me, he has, in *England*, met with a sandy earth, that turns wood into stone, tho' there be no petrifying spring near the place; and this it does in a better manner than any water I have yet seen. And the like differences would, probably, be taken notice of in other mineral bodies, if mens prepossessions did not make them ascribe the variations they meet with in their experiments, rather to any other cause, than the unsuspected difference of the materials employ'd in them.

Nor is it only among mineral bodies of the same name, that such a diversity is to be found; 'tis very probable, that a greater disparity may be discover'd, both among vegetables and animals, if narrowly examined, which are reputed of the same nature, than hath been yet taken notice of. Botanists, indeed, have shewn a commendable curiosity in subdividing plants of the same denomination; and few naturalists are ignorant, that there are, for instance, many sorts of roses, and of apples, which differ

widely betwixt themselves; as the red rose, and the white, the crab, the pippin, and the pearmain. But, besides these differences, which are obvious enough to be register'd by botanic authors, there may be more undiscern'd ones betwixt the individuals of the same ultimate subdivision of plants, arising from the temperature of the air; which makes, for example, fena growing in *England* to differ much from that of *Alexandria*; and from the nature of the soil, as appears by the change produced in wild simples transplanted into gardens, and many other causes. We often see, that one rose differs from another of the same kind, and one pearmain from another pearmain. To which we may add, that the upper crust, or surface of the earth, being impregnated with subterranean exhalations of several sorts, and temper'd with variety of juices, it's very possible that some particular plant may attract such a juice out of a determinate spot of ground, as to give it exotic qualities, and make it differ even from the neighbouring plants of the same kind. Thus, I remember, I met with, in *Switzerland*, a sort of very heady wine, that otherwise seem'd to be sack, tho' it grew amongst the mountains of the country; but I could not believe it, till they assured me, that it received its inebriating quality, with the rest of those that remarkably distinguish'd it from the other wine of those parts, by growing on a little spot of ground, whose entrails abounded with sulphur. And since I have mention'd wine, I may further remark what a great change is made in that liquor, when, upon the recess of the spirits, and more volatile sulphureous parts, it degenerates into vinegar; whilst little diminution of quantity, or any other alteration, appears upon this change. And tho' this change is familiar to us, yet who knows what others may be produced in bodies, with whose alterations we are unacquainted; whilst the eye, which is often the only sense employ'd about judging of them, discerns no difference? Thus, we may daily observe the superannuated seeds of plants, after having been long kept beyond their due time, lose all their germinating power; tho' they retain all their obvious qualities. Urine is much used by dyers, and several other tradesmen, who indifferently employ it, without examining whether it be rich in salt, and how long it hath been kept; tho' chymists, who frequently have occasion to distil it in large quantities, assure me, that they find a notable difference therein; that of healthy young men, abounding much more with volatile salt, than that of sickly or aged persons. They say, also, that the urine of such as drink wine freely, is much fuller of spirituous and active parts, than that of those who drink only beer or water. And tradesmen, who boil their several commodities indifferently in any urine, may thereby sometimes commit considerable errors: for fresh urine, wherein the saline parts are entangled among the rest, will endure to be boiled above one half or two thirds away, without losing its volatile salt and spirits; whilst that which has been kept for several weeks, is liable to a putrefaction, whence the component pars fall asunder; and the saline ones, extricating themselves from the rest, will, upon a very gentle heat, evaporate, and leave a phlegmatic, unactive liquor behind them. Having caused some urine to be buried in earthen vessels in a dunghil, to putrefy for five or six

six weeks, I was kept from employing it till it had lain there between four and five months; and observing, when I caus'd it to be taken out, that the covers of the vessels had not been well luted on, and were, besides, in some places, crack'd; I suspected that the heat of the dung had not only loosen'd the saline parts of the liquor, but driven them away; and accordingly, by distilling it with a very gentle heat, and in a very high cucurbit, we obtain'd, instead of an active and saline spirit, a languid and nauseous phlegm. And how great odds there may be betwixt some experiments, made with new and putrefied urine, may be easily conceiv'd by him who knows what effect salts have in the production of colours; and is acquainted with their efficacy in those other mechanical experiments, wherein urine is employ'd.

Thirdly, there is a great difference to be found among many things prepared by art, that bear the same general name; which may proceed, from what we have already observed, in the materials, of which such bodies are composed, or from the means used in preparing them. But we shall, at present, mention only two sorts of factitious bodies; such as are not sufficiently purified, and such as are purified too much. And in their preparations.

It is very certain, that many chymical experiments, deliver'd by sober authors, have been judg'd false, only because the menstrua, or other materials employ'd in the unsuccessful trials, were not as highly rectified, or, otherwise, as exquisitely depurated, as those that were used by the original experimenter; so that the fault of a bad menstruum, is often injuriously imputed to an excellent artist. That experienc'd chymist *Van Helmont*, endeavours to explain the manner wherein the *calculus humanus* is generated, by the coagulation immediately ensuing upon the mixture of the two volatile spirits, of urine, and of wine. This noble experiment has, by many, been unsuccessfully tried, and therefore by them condemned as a chymical fiction; and the first, and, I think, the second time we attempted to make that coagulum, we found nothing of what we expected: but at length, thinking it possible that the spirits we employ'd had not been sufficiently exalted, we dephlegm'd some by more frequent and tedious rectifications; and thence, by more accurate trials, were satisfied that *Van Helmont* had not misinform'd us. So, likewise, the same author, extolling the tincture or solution of amber, made with spirit of wine, as a noble stomachic, cephalic, &c. many physicians and chymists have attempted to prepare this tincture, with such bad success, that they declare, *Helmont* either deliver'd what was false, or conceal'd some considerable circumstance of the process. But having digested well dephlegmed spirit of wine upon high-colour'd and very finely powder'd amber, and placed them in a very gentle heat; we have, several times, obtain'd a true tincture of amber, discernible both by its smell and taste. And, to shew that this colour proceeded from a real solution of the more subtile parts of the amber, we pour'd some drops of it into water; when, the spirit of wine suddenly diffusing itself; the dissolv'd amber was plainly discernible, swimming like a thin film upon the surface of the liquor, whence it gradually exhaled into the air.

The Usefulness of Philosophy.

There may, likewise, as we have tried from pure salt of tartar, be drawn, with spirit of wine, a pretty high tincture, and of a remarkable taste ; but upon lately trying to draw this tincture with spirit of urine, which, unknown to me, was much too weak for that purpose, I found that after I had kept the glass a while in digestion, the salt of tartar had drawn to itself, and imbibed the aqueous particles of the spirit ; and being thereby, in part, dissolv'd into a liquor, the subsiding salt was, by the interposition thereof, protected from the action of the spirit of wine ; which, being thus dephlegm'd, would not mix with the saline liquor, but swam entirely above it. This I shall add, in general, that the *German* chymists are commonly so accurate in the rectification of their spirit of wine, that, in *England*, where we are less careful in that particular, it is common, for those experiments of theirs, to be unsuccessfully try'd, wherein the alcohol of wine is requisite.

And it is not only in menstruums, but in many other bodies, that the want of an exquisite depuration may produce a variety of events in experiments : as, for instance, it has been complain'd of by sober men, that their preparations of silver, tho' never so carefully made, have been apt to prove violently emetic ; tho' we have not observ'd a well-prepar'd medicine of duly refined silver to work by vomit, even in women and children, but by stool, or urine. We cannot, however, wonder at the violent operation of medicines made with ordinary silver ; for not only that of coin is allay'd with about a twelfth part of copper ; but even that which is commonly, at a great rate, sold for refined silver, is not often sufficiently freed from its copper ; as I lately manifested in the presence of one of our most eminent refiners, by dissolving some of his purest silver in his own *Aqua fortis* ; for the greenness of the solution quickly betray'd the baser metal : and no wonder, for I have seldom seen our chiefest refiners blow off from their silver, upon the test, above half its weight of lead ; whilst we think not our silver sufficiently refined, till it has been freed from five or six times its weight thereof ; and then it has afforded a solution as clear as water, with only, now and then, a scarce discernible tendency towards sky-colour.

Now, that ill effects, by the mixture of copper, may be produced in such medicines, as ought to be of pure silver, the violent emetic qualities of the former will scarce suffer us to doubt. And, as in mens bodies, so in other subjects, those experiments may easily fail the artist's expectation, when he hopes to perform, by a mixture of those two metals, that which requires pure silver alone. And as silver, so gold is very often employ'd for pure, when 'tis otherwise : the foliated gold, commonly sold here in *England*, how fine soever reputed, is not altogether free from the pollutions of other metals ; for our gold-beaters, tho' for their own profit they use the finest gold they can get, yet scruple not to employ coin'd gold ; and this the mint-masters allay with copper, or silver, to make it stiff, and less subject to waste by attrition. And as for those goldsmiths, and chymists, who think their gold most exquisitely refined, when they have blown from it, on the test, a due proportion of lead, they may therein be sometimes mistaken

mistaken; for tho' the lead may carry away with it all the copper that debases the gold, yet the gold does not always, after this, remain free from silver: nay, the most skilful refiner that I ever knew, hath, several times, affirm'd to me, that after cupelling fine gold, with lead, the gold has retain'd, and protected from the fire, a proportion of silver that lay lurking in the lead, and was afterwards separated from the gold by *Aqua fortis*, tho' in so small a quantity, that the experiment was not gainful.

But as many experiments succeed not, because the menstrua employ'd about them were not pure enough; so some miscarry, because such menstrua are too exactly depurated: for it is not so much the purity of liquors in their kind, as their fitness for the particular purpose to which they are design'd, that is to be principally regarded in experiments. For instance, we have sometimes made pieces of paper, and linen, appear all on a flame, without either burning, singeing, or so much as discolouring them. This is perform'd, by moistning the paper or linen thoroughly in weak spirit of wine, and then bringing them to the flame of a candle, by which the spirituous parts of the liquor will be fired, and burn a pretty while, without harming them; but if the experiment be tried with exquisitely rectified spirit of wine, it will not succeed: however, the flame of spirit of wine is so hot, that I have, in lamp-furnaces, employ'd it instead of oil, and with the same flame, have melted leaf-gold. The reason, therefore, why paper is not burned by the flame that plays about it, seems to be, that the aqueous part of the spirit of wine being imbibed thereby, keeps it so moist, that the flame of the sulphureous parts of the same spirit cannot fasten to it; and, accordingly, when the flame ceases, the paper remains moist. On the other hand, having purposely plung'd paper into dephlegm'd spirit of wine, it was very readily kindled, and burn'd by the flame thereof. And one of our best ways to try the purity of spirit of wine, is grounded on this very supposition: for dipping a cotton wick therein, and setting it on fire, if the flame fasten on the wick, it is a sign the spirit is pure; but if it does not, we conclude it to be not sufficiently dephlegm'd. Some artists, likewise, observe, that *Aqua fortis* will work more readily on lead, for being allay'd with water. I have used an *Aqua fortis* so strong, that it would not well dissolve silver, unless first diluted with fair water. And I have had an unwelcome proof, that liquors may, by too exquisite a depuration, be made unfit for some purposes. For having, to gratify some friends, made a certain menstruum, wherewith we had perform'd surprizing things upon gold, we took care, against the time of their exhibition, to separate it from whatever was of an aqueous or earthy nature, more exactly than ever before. But coming to make use of this sort of menstruum, we found, that instead of performing its operation upon gold better than usual, we could do nothing at all with it: for it would not now, even by heat, be brought to touch gold, tho' it used, unassisted, to dissolve it. But having, for trial-sake, taken a little of this numerical parcel of liquor, before it was so carefully rectify'd, it dissolv'd crude gold, as well as we had reason to expect. And it deserves to be consider'd, whether or no, in the extraction of the tinctures of several
bodies,

bodies, chymists do not put themselves to a needless and prejudicial trouble, by refusing to employ any other spirit of wine, than that which is highly rectified: for, tho' in many substances, the parts desired by the artist being sulphureous, the menstruum is the better for an exquisite dephlegmation; yet in several others, the useful and efficacious parts are the saline, which make them more freely impregnate such liquors, as have some aqueous mix'd with their sulphureous parts.

Unregarded
circumstances
may prevent the
success of experi-
ments.

Thus much for the manner wherein experiments may miscarry, upon account of their materials. Let us next consider the contingencies whereto they are obnoxious, from circumstances that are either unobvious, or scarce discernible, till the trial is over. A physician of unquestionable veracity assured me, that, as upon taking a journey, he lent his laboratory to a friend in *Holland*, wherein, among other things, was great store of *Aqua fortis* of several compositions, which he had made to employ about his scarlet dye; his friend soon after sent him word, that by digesting gold with an *Aqua fortis*, he had separated the tincture, or yellow sulphur, from it, and made it volatile; the remaining body growing white; and that with this golden tincture he had turned silver into very perfect gold, with considerable profit. Upon this news, the doctor presently return'd to his laboratory, and did, himself, with the same *Aqua fortis*, several times, draw a volatile tincture of gold, which turn'd silver into true gold. He farther affirm'd, that out of an ounce of gold, he thus drew as much sulphur, as sufficed to convert an ounce and a half of silver into that noblest of metals. This I am the more disposed to believe, because I have found, that a yellow substance, or tincture, is obtainable from gold; and, because I am tempted to think, that silver may have in it a sulphur capable of being advanced, by maturation, into a golden one*. For I have been assured, by men very experienc'd in metalline affairs, that they have seen, sometimes by corrosive liquors, and sometimes by the operation of common sulphur, especially well open'd, and associated with fit salts, silver to afford some grains of very pure gold. But the doctor found himself much mistaken in his hopes of growing rich by this experiment; for a while after, endeavouring to make it again, it succeeded not; which he ascribes to a defect in the *Aqua fortis*, and therefore has attempted the same work afresh. But since all his trials have been hitherto fruitless, 'tis not improbable, that the disappointment proceeded from some other more obtruse cause; for we find such accidents have sometimes befallen artists irreparably. *Glauber* tells us of several ways, by which he made gold once, but could not do it again. The prince of *Mirandula*, in his treatise *de Auro*, tells us of several persons, whom he knew had the like success in preparing both gold and silver. And I could instance in my own acquaintance, those who, having once or twice made *Luna fixa*, (which, wanting only the tincture of gold, abides the trial of *Aqua fortis*, &c) or some other gainful experiment, have since, in vain,

* *M. Homberg* declares, he has actually | the *French Memoirs* for the year 1709, p.
converted silver into gold, by heat. See | 139—143.

attempt-

attempted the like ; and yet cannot be prevailed with to desist from prosecuting their uncertain hopes. And the most experienc'd mineralist I ever met with, has assured me, he should quickly grow rich, could he but constantly perform what he has several times perform'd *. It may be very serviceable to know, that many experiments succeed, when made with small quantities of matter, which fail in greater : several projectors, especially chymists, have very dearly bought the knowledge of this truth. For it often happens, that an unwieldy quantity of matter, cannot be expos'd, in all its parts, to a just degree of fire, or otherwise so well manag'd, as a less : hence many have ruin'd themselves, by obstinately attempting to make even real experiments more gainful.

It is deliver'd by the Lord *Verulam*, and other naturalists, that if a rose-bush be carefully cut, as soon as it has done bearing in the summer, it will again bear roses in the autumn. Of this, many have made unsuccessful trials, and thereupon report the affirmation to be false ; yet, I am very apt to think, that my Lord was encouraged by experience, to write as he did. For, having been particularly solicitous about the experiment, I find by the relation, both of my own, and other experienc'd gardeners, that this way of procuring autumnal roses, will, in most rose-bushes commonly fail, but succeed in some that are good bearers ; and accordingly, having this summer made trial of it, I find, that of a row of bushes, cut in *June*, by far the greater number promise no autumnal roses ; but one that hath manifested itself to be of a vigorous and prolific nature, is, at this present, indifferently well stored with those of the damask-kind. There may, also, be a mistake in the species of roses ; for experienc'd gardeners inform me, that the musk-rose, will, if it be a lusty plant, bear flowers in autumn, without cutting : and therefore, that may unjustly be ascribed to art, which is the bare production of nature. Cinnamon rose-bushes thrive so much better by cutting, than several other sorts, that I remember, this last spring, my gardener having about the middle of *April*, cut many of them in my garden, I saw about the middle of *June*, many of the same bushes, plentifully adorn'd both with buds and blown flowers.

An uncertainty, like this, has been likewise observ'd, in attempting to produce different sorts of fruit from the same tree ; however, we have lately seen various sorts of pears, fed by the same plant ; and three and twenty sorts of apple-grafts flourishing upon the same old stock ; most of which were adorned with fruit. Nay, and tho the fruits be not of the same denomination, yet, if they be of kin in nature, they may, very possibly, be brought to grow on the same tree ; for we lately gather'd both apricocks and plumbs from the same tree, and expect other sorts of stone-fruit from it. But, for fruits of very different natures, to be prosperously nourished by the same stock, is so difficult, that we can only reckon it among contingent experiments : for tho both *Pliny* and *Baptista Porta*, relate their having seen an

* To this general purpose, we may observe | stances, *Aqua regia* will dissolve silver. See with *M. Homberg*, that, in certain circum- | the *French Memoirs* for the year 1706, p. 128.

The Usefulness of Philosophy.

example of it; and, tho the great *Dr. Ward* assures me, he has particularly taken notice of pears growing upon an apple-tree; yet, certainly this experiment has been, for the most part, but very unprosperously attempted; nor have I yet ever seen it succeed, tho try'd with very great care and industry. And in the same garden, where I gathered the apricocks and plumbs above-mentioned, I saw the ciens of a pear-tree, so skilfully grafted upon an apple-stock, that it flourish'd with blossoms in the spring; and gave me great hopes, that it would bear fruit the last summer; but it has baulk'd my expectation: as many other plants, so grafted in the same garden, have, for many years, deluded the skilful master of it; who assures me, that tho several of them did, for some years successively, afford promising blossoms, yet they all decay'd without yielding any fruit. This seems somewhat strange, because we have gather'd pears from a shoot affirmed to have been grafted upon a quince-tree; and *Kircher* tells us, "'tis found by experience, that a peach grafted upon a mulberry, will prosper and bear fruit." And we daily see, that as little as a white-thorn and a pear-tree seem allied, a cien of the latter will prosper very well, grafted upon the stock of the former.

To contingent experiments, we may refer what is deliver'd by those, who affirm, that if a lixivium made of the fixed salt of a plant, be frozen; there will appear in the ice the image of the same plant: for we have frequently made this experiment without the promised success; and neither a solution of the salt of wormwood in fair water, nor the decoction of that plant, would, when frozen, exhibit any thing like its figure in the ice. 'Tis common, indeed, to find these liquors, solutions of sugar, salt, &c. frozen into odd figures; and even common water will do the same: which need not be wonder'd at; since it glides thro earths abounding in saline particles of particular natures: whence, perhaps, it is, that dyers find some waters very fit, and others very unfit, for their purposes. Yet, because two or three sober writers seriously relate some stories, of this nature, upon their own observation, I am content to rank their experiments rather among the contingent, than the absolutely false ones: for it is possible, that among the many figures which frozen liquors sometimes put on, there may be something so like a particular plant, that, view'd with a favourable eye, it may seem to exhibit the picture of the calcin'd vegetable. Setting a fine green solution of good verdigrease to freeze, in snow and salt, that containing much of the saline parts of the grapes, coagulated upon the copper they corroded; I obtain'd an ice of the same colour, wherein appear'd several little figures, so like to vines, that we were somewhat surpriz'd at the experiment. And what encreas'd our wonder, was, that, another part of the same solution frozen in a different vial by the bare cold of the air, afforded us an ice angularly figur'd, but not at all like that made by the application of snow and salt. And having, for further satisfaction, suffer'd that ice, wherein the vines appear'd, to thaw of itself, and then to freeze a second time in the same vial, after the same manner; we could not discern in the second ice, any thing like that we had admired in the first. And in wine and vinegar, as much

as those liquors partake of the nature of the vine, we never, after congelation, observ'd any peculiar resemblance thereto.

The experiment of burning with ice, as with a glass-lens, tho' prescribed without any notice taken of the difficulty in it, yet, both we and others, who have industriously try'd it, meet with such discouraging circumstances therein, especially from the unequal texture of most ice, that it may well be referr'd to those, whose constant success is not to be rely'd on. In the trade of dying, there is scarce any ingredient of so great and general use, as woad; for tho', of itself, it dyes but a blue, it is used to prepare the cloth for green, and many other sadder colours, when they are design'd to be permanent; and not to fade: but in boiling of it, to make it yield, or strike its colour, there are some critical times, and other circumstances, to be observed; an easy mistake wherein often defeats the dyer's expectation, to his very great loss; which, sometimes, he knows not to what he should impute it: and of this, I have heard several of them complain. And, therefore, many of our less expert dyers, to avoid those hazards, leave off the use of woad, tho' growing plentifully in *England*; and, instead of it, employ indigo, tho' it cost them dearer, as being brought hither from *Spain*, *Barbadoes*, or the *East-Indies*.

Our *London* refiners, when to part silver and copper, they dissolve the mixture of them in *Aqua fortis*, afterwards greatly dilute the saturated menstruum with fair water, and then with copper-plates, strike down the silver. But because much copper thus remains in the menstruum; that the liquor may be improv'd to the best advantage, they pour it upon what they call whiting; that is, white chalk or clay, finely powder'd, cleans'd, and made up into balls, wherewith the tinged parts incorporating themselves, will, in some hours, constitute a sort of verditer fit for painters, &c. leaving the rest of the menstruum an indifferently clear liquor; whence they afterwards, by boiling, obtain a kind of salt-petre, fit, with the addition of vitriol, to yield them a new *Aqua fortis*. But sometimes the refiners cannot make this verditer for a great while together, yet know not whence their inability proceeds. Of this contingency, I lately heard one of the most eminent of them complain; tho', for his part, he had found a remedy for it: which is, to warm the menstruum well before it be poured on the whiting, whereon the tinged parts would then fasten, tho' not when poured on cold.

One of the overseers of the chief copperas-works we have in *England*, assured me, that by the mistake or neglect of a circumstance, in point of time, they had frequently lost some thousand pounds weight of vitriol at a time; which would degenerate into an unctuous substance, not to be reduced into good vitriol again, unless by the tedious way of throwing it abroad, and exposing it, with the unprepared stones, to the rain and sun, to be open'd anew, and fitted to yield it, after the same manner with those crude minerals.

Josephus Acosta, who diligently survey'd the famous mines of *Peru*, and, for one who was not a chymist, has deliver'd many considerable and judicious observations about them, says, "it is strange to see, not only the diffe-

The Usefulness of Philosophy.

“rence betwixt the refining of metal by fire, and, without it, by quicksilver; but also, how some of these metals refined by the fire, will not melt, when that is blown with any artificial wind, but requires the natural air. The metal of the mines of *Porco*,” says he, “is easily refined with bellows; whilst that of the mines of *Potozi* cannot be fused with bellows; but only by the breath of their small furnaces, built upon the sides of mountains, directly where the wind lies: and tho’ it be hard to assign a reason of this difference, yet the thing is certain, and confirm’d by long experience.”

If any trade obliges the artificer thoroughly to understand the management of the materials employ’d therein, it is that of glass-making; yet, even in the most ordinary operations of this art, there happen, now and then, little accidents, which, tho’ they know not well what to ascribe to, are yet capable of hindring them from performing what they have done a thousand times. An eminently skilful workman, whom I had purposely engaged to make some vessels that required more than ordinary dexterity, was, lately, unable to make metal tolerably fit to be used; and therefore he desired me to come again another day, when he would try to retrieve his misfortune. But, returning by appointment, his metal again prov’d unserviceable; and instead of being colourless when cold, it seem’d stain’d with blue and yellow, and was, besides, too brittle; so that it need be no such wonder, if philosophers and chymists, sometimes miss the expected event of an experiment but seldom try’d; since tradesmen themselves cannot always accomplish what, if they were not able frequently to perform, they could not subsist.

It is affirmed by *Helmont*, and others, who treat of the *Lapides cancerorum*, that they grow within the skulls of craw-fishes; but I have known good anatomists complain, that they have there sought them in vain; yet we have often taken those stony concretions out of the heads of such fish*. But passing lately thro’ *Hungerford*, a town famous for craw-fish, we made diligent enquiry into their nature; and were there inform’d, that the concretions above-mentioned, are to be found in their heads, only about that season of the year wherein they shift their shells; and that at other times, several persons had in vain endeavour’d to obtain them. And, indeed, having at the last time of my being there, about the latter end of *June*, caus’d many of the larger sort to be taken out of the water, we found those little stones in the head of but one of them; tho’ about a fortnight before, we had taken out of the usual part of their heads, several such concretions, as to magnitude and shape; but so soft, that we could easily crush them be-

* We are assured by *Monf. Geoffroy*, from his own observation, that the stones taken out of the heads of craw-fish, belong not to the brain, but the stomach of the creature, which lies underneath; that they do not supply matter for a new shell, but are to be found after the shell is formed; that the animal, in changing its shell, changes also its stomach, and, perhaps, its intestines; that these stones appear not, but at the

time of their annual change of shell, when they are weak, sick, and cease to feed; that afterwards, the stone is surrounded with a new stomach, and diminishes insensibly, till it entirely disappears; and, lastly, that these stones, with the membrane of the old stomach, serve to nourish the animal, during its sickness, upon its change of shell. *Memoir. de l’Academ. Roy.* A. 1709. p. 409.

twist our fingers. And certainly, mistakes in point of time, have greatly prejudiced the reputation of many truths. *Afellius* ingenuously acknowledges, he had nearly miss'd the discovery of the lacteal veins, because, having at first suspected those unlook'd-for white vessels, which he took notice of in the mesentery of a dog, dissected alive, to be some irregular ramifications of nerves; he was much confirm'd in his conjecture, by the next dog he open'd: for taking him at an inconvenient time, after feeding, the slender vessels he look'd for, being destitute of chyle, were not conspicuous; so that he had lost the benefit of his first lucky observation, had not his sagacity led him to suspect, that if a dog were plentifully fed, at a convenient distance of time before dissection, the vessels, swell'd with alimental juice, would be more discernible: and, in pursuance of this conjecture, he made that famous discovery of those veins.

We may say, in the general, that such circumstances, as are very difficult to observe, or seem to be of no concern in an experiment, may yet, in many cases, have a great influence in the event of it. If on either pole of a good arm'd load-stone, you gently draw the back of a knife, which has not before receiv'd any magnetic influence; you may observe, that if the point of the blade have, in this motion, pass'd from the equator of the stone towards its pole, it will attract one of the extremes of a librated magnetic needle: but if you take another knife, that has never been invigorated, and, upon the same pole of the load-stone, thrust the back of it from thence towards its equator, the point of the knife will, by this bare difference of position in the blade, acquire so different a magnetic property, or polarity, from that which was given to the former knife, by the same pole of the load-stone, that it will not attract, but rather seem to repel that end of the magnetic needle which was attracted by the point of the other knife. This improbable experiment we have made, not only by passing slender irons upon the extremities of arm'd load-stones, the breadth of whose steel-caps may render it somewhat less strange; but even by affrictions of such irons upon the pole of a naked terella. But how far this surprizing observation insinuates the operations of the load-stone, to be perform'd by streams of small particles, perpetually issuing out of one of its poles, that, after wheeling about, re-enter at the other, we shall not now examine; tho' this seems one of the most likely phenomena we have met with, to hint a probable magnetical hypothesis. But hence it plainly appears, how great an influence a circumstance, which none but a magnetic philosopher would take notice of, may have on an experiment.

Artificers give very different tempers to steel, by holding it in the flame, or heat, for different minutes of time. I have a graver, said to be of *Damascus* steel, whose temper is such, that I cannot let it down by any art; tho' one, who has had the opportunity of making more than ordinary enquiry into matters of this nature, assures me, he can easily soften this kind of steel, by only taking it off the fire at a certain juncture of time; differing from that observ'd in softning the common gravers. And who knows, but that in many other experiments, seemingly despicable and unheeded circumstances may be of great moment; tho',

The Usefulness of Philosophy.

thro' want of particular observations, men have not generally taken notice of their importance.

Many planters have, with wonder, observ'd, that some grafts of cherry-trees, for example, have yielded fruit the same year wherein they were grafted; (as I have observed some plants to bear in the same quarter of the year) and others not till the year after their infition; tho' neither in the goodness of the graft, nor in that of the stock, they had remark'd any disparity, to which this difference could be ascribed; and, therefore, the bearing, or not bearing of the ciens of a cherry-tree, the first year of its infition, is, by them, look'd upon as a thing merely contingent. Yet, I am inform'd, by the trials of more than one of the most skilful and experienc'd grafters of these parts, that a man shall seldom fail of cherries from the graft, the same year in which the infition is made, if he take care the graft be of a good kind, and have blossom-buds upon it; but if they were only leaf-buds, it will not bear till the second season. And to discern such buds as are fit to produce blossoms, from such as will display themselves only in leaves, is no difficult matter; the former sort being more full, large, and round than the latter, which also lie more flat and close to the graft.

By the *Virgula divinatoria*, many mineralists pretend to discover the latent veins of metals. Some use a forked hazel, whose horns they hold by the ends, one in each hand: and others content themselves with a hazel-rod of the same year's shoot, which they bind on to another streight stick of any other wood; and walking softly with it over those places where they suspect metals to be conceal'd, they say, that, if they pass over a metalline vein, the wand will, by dipping there, discover it. And I know some who affirm, that by holding metals successively in that hand where the rod is, it may be discover'd what determinate metal predominates in the vein; for that when the metal wherewith the mine chiefly abounds, is held in the same hand, the wand will manifestly bow more strongly, than when it is held in conjunction with any other metal. What to determine, as to the truth of this experiment, I know not: for *Agricola* himself, after a long debate concerning it, tells us, that an honest metallist will not use this rod; and that, if he be skilful, he may do without it; "tho' indeed, says he, it does afford some actual signs of veins." *Kircher* informs us, that, having exactly try'd the experiment with metals, he could not find it, in any measure, to succeed: and we ourselves, having several times made trials of it in the presence of the most confident assertors of its truth, could not be satisfied, that the wand did stand either to the metals placed under it, or to the metalline veins, when carry'd over mines whence metalline ore was at that very time digging out. But, on the other side, many eminent authors, and even our diligent country-man *Gabriel Plat*, ascribes very much to this detecting wand; and many persons, in other things very far from credulous, have, as eye-witnesses, solemnly asserted the truth of the experiment to me. And one gentleman, who lives near the lead-mines in *Somersetshire*, leading me over those parts of them where we knew there run metalline veins, made me take notice of the inclination of the wand when we pass'd
over

over a vein of ore; and protested that the motion of his hand did not at all contribute to the inclination of it; but that sometimes, when he held it very fast, it would bend so strongly, as to break in his hand. And to convince me that he believed himself, he did, upon the promises made him by his dipping-rod, put himself to the great charge of digging in untry'd places for mines. Among the miners themselves, I found some who made use of this wand, and others that laugh'd at it. This I must take notice of, as peculiar to the experiment, that the most knowing patrons of it confess, that, in some mens hands it will not succeed; some hidden property in him who uses the wand, being able, as they say, to overpower and hinder its inclinatory virtue. To which I must add, what a very famous chymist, who affirms himself to have try'd many other things with it, besides those that are commonly known, very solemnly profess'd to me, upon his own knowledge, that, in the hands of those very persons wherein the rod will work, there are certain unlucky hours, govern'd by particular planets and constellations, during which, it will have no effect. But of this experiment I must say, as I do in all doubtful cases, that those who have seen it, may much more reasonably believe it, than those who have not.

'Tis not only in experiments, but observations also, that much may be ascribed to contingency; witness the great variety in the number, magnitude, position, figure, &c. of the parts of a human body, taken notice of by anatomical writers; about which many errors would have been deliver'd, if the frequency of dissections had not enabled men to discern betwixt those things that are generally and uniformly found in anatomiz'd bodies, and those which are but rarely met with. I was lately present at a dissection, where we observ'd, that the interval betwixt two ribs, was, near the backbone, fill'd up with a thick bony substance, which seem'd to be an expansion of the ribs, and appear'd not to have grown there upon occasion of any fracture, or other mischance. Near the same time, being at a private dissection of a large young body, an ingenious professor of anatomy, there present, chancing to cut a great nerve, spy'd in the substance of it a little of a very red liquor; but, concluding it to be blood, I presently suspected, that it might proceed from some small unheeded drop, taken off, by the brushy substance of the nerve, from the knife wherewith it was cut. Wherefore, carefully wiping a dissecting knife, I cut the nerve asunder in a different part, and found another very little drop of pure blood in the substance of it, as before. This I did again, elsewhere, with like success; and shew'd it to the by-standers, who were surpriz'd to see a blood-vessel in the body of a nerve. This I the less admir'd, because I have, in the retina of an oxes eye or two, observ'd little turgent veins, manifestly full of blood.

We farther observ'd, in the same body where we took notice of the irregular conjunction of two ribs, that the lungs, which were very sound, had a supernumerary lobe on one side, which differ'd so little from the others, that we did not, till we had display'd the whole, take notice of it. And I remember, in another dissection, the lungs, which otherwise appear'd

*Observations
contingent, as
well as experi-
ments.*

The Usefulness of Philosophy.

pear'd sound, seeming, in several places, to be fasten'd to the ribs ; two ingenious anatomists present, affirm'd, the one, that he had never seen any lungs, unless excessively morbid, adhering to the thorax ; and the other, that he had scarce ever open'd a diseased body, wherein the lungs did not thus adhere.

Many eminent authors declare, they have seldom fail'd to find the token of virginity among several females of their dissecting ; whilst many other very eminent and experienced artists peremptorily profess, they have seldom or never found it in persons of the most undoubted chastity : and certainly it is very strange, that, about a matter which seems so easily determinable by sense, accurate and sober men should so widely disagree.

Tho' Dr. *Harvey*, and Dr. *Higmore*, both insist on the production and changes observable in hens eggs, as the patterns whereto the generation of other animals may be referr'd ; yet, in the progress of nature in the formation of a chick, we have often observ'd considerable variations, in point of time, and other circumstances, from what they deliver. And this diversity may easily proceed from the different constitutions of hens, their differing assiduity in sitting on their eggs, the different qualifications of the eggs themselves, and several other particulars of the like nature. And taking notice of this to Dr. *Higmore*, he readily acknowledg'd, that he himself had, likewise, observ'd several circumstances in eggs, whilst they were hatching, which varied from those set down in his book ; tho' he had there accurately express'd the changes he discern'd in those eggs, which, at that time, afforded him his observations. And, indeed, there are certain things of such a nature, that the accuracy of scarce any single man, in making an observation about them, can secure him from appearing unskilful, or unfaithful in it, unless those who shall afterwards examine the thing, shew more than ordinary equity and sagacity.

He who first affirm'd, that a needle invigorated by a load-stone, constantly turn'd its extremes to the opposite poles of the earth, could scarce suspect himself of having deliver'd any thing which he had not carefully try'd : yet which of those two excellent pilots, *Oviedo* and *Cabot*, first in *America* compar'd the meridian line, afforded by magnetical needles, with one mathematically drawn, and thereby observ'd the variation of the needle, or its declination from the true meridian, might easily conclude our former observer mistaken. And this second observation might appear to have been as carelessly made to an hundred other observers, if navigation had not made it appear, that the declination of the needle is far from being the same in all places : for tho' *Cardan* affirms the load-stone to decline as many degrees, as the pole-star is distant from the pole of the world ; yet common experience sufficiently manifests the falsity of that assertion. For about the islands of the *Azores*, especially that of *Corvo*, over which the first meridian is supposed to pass, the magnetic needle hath been observ'd to respect the poles, without any sensible declination from them ; but, in other places, it varies sometimes eastward, sometimes westward, more or less ; so that our venturous countryman, Captain *James*, observ'd it, in 63 degrees, north lati-

latitude, to be no less than $27^{\circ} 48'$. And a late learned mathematical writer makes the declination, at *Davis's* streights, to amount to what is almost incredible, 50° . Nay, this deflection of the needle, sometimes to one side of the meridian, sometimes to the other, happens with so much irregularity, that both *Kircher*, and other magnetical writers, almost despair of reducing the observations of this kind to any general hypothesis. And a great sailor assur'd me, that near the coast of *Greenland*, he found the variation of the compass to be 22° . and not very long after to be scarce any at all; which strange alteration he knew not what to make of. And perhaps very few, even of the exactest of these observations, made an age since, would now appear accurate to those who should examine them in the very same places, and the very same manner, wherein they were formerly made. So that the most diligent of those observers would appear negligent to us, if the sagacity of some of their successors had not prompted them to suspect, that even upon the same spot, the needle's variation may vary. And having, not long since, inquired of an excellent *English* mathematician, what he had observed concerning this alteration of the needle's variation; he told me, that by comparing of ancient observations with those made by himself, and other accurate mathematicians at *London*, he had found the declination constantly to decrease; and, as he conjectured, 12 or 13 minutes in a year*. And it will be yet more difficult to set down any observation of this nature, which shall appear exact to posterity, if that strange thing be true, which was related to *Kircher*, by a friend of his, who affirms himself to have observ'd a notable change of the needle's variation, at *Naples*, after a great fiery eruption of the neighbouring mountain *Vesuvius*; which alteration he rationally suspects to have proceeded from the very great change made in the adjacent subterranean parts, by that great conflagration. And, it seems, the same observation has been elsewhere made by mathematicians. For *Fournier* tells us, that, since the great burnings of *Vesuvius*, the declination has notably chang'd in the kingdom of *Naples*. And the same author says, there are persons, who have observ'd, that the same needle, which declin'd 5° . upon the surface of the earth, being carry'd down very low, into certain caves, declined quite otherwise; tho', possibly, those who made the observation, might be mistaken, without suspecting it themselves. For I should scarce have imagined, unless my own particular observation had inform'd me, in how great a variety of stones and other fossils, the ore of iron may lurk disguised: so that 'tis no way incredible, that chymists themselves, and, much more, that mathematicians, and others, not being aware of this particular, may presume, because they saw not any minerals, like the vulgar

* Dr. *Halley*, from considering the different variation of the needle, in different parts of the terraqueous globe, has advanced a very ingenious hypothesis to solve the phenomena of it, by supposing that the whole earth is one great magnet, having four magnetic poles, or points of attraction, two near each pole of the equator; and that in the parts of the world near any one of these magnetic poles, the needle is govern'd thereby; the nearest to the pole being always predominant over the more remote. See *Philos. Transf.* N^o 148. p. 208.

The Usefulness of Philosophy.

iron ore, in the deep caves above-mention'd, that there is nothing of that metal there; when, indeed, there may be enough to occasion that deflexion of the needle, which, especially if it be strongly excited, may be often drawn aside by iron, or other magnetic bodies, at a greater distance, than those, who have not try'd, would suspect. And this may, perhaps, be the reason, why, in the little island of *Ilva*, upon the coast of *Italy*, where they dig up iron, and plenty of load-stones, of which, I have seen in *Tuscany* of a prodigious bigness; there is, in the neighbouring places, such a strange disparity of the needle's variation, as curious men have recorded. But magnetical and anatomical observations, are not the only ones, which are subject to disagree, without the negligence of those who make them.

I forbear to insist on medicinal experiments and observations, because they are so numerous, and universally subject to such uncertainties, that it would be tedious. It is, indeed, much more difficult, than men can imagine, to make an accurate experiment in physic; for often, the same disease proceeding, in several persons, from quite different causes, will be increas'd in one, by the same remedy which has cured it in another. And not only the constitutions of patients may as much alter the effects of remedies, as the causes of diseases; but even in the same patient, and in the same disease, the single circumstance of time, may have almost as great an operation upon the success of a medicine, as either of the two former particulars. But, besides the general uncertainty, to which most remedies are subject, there are some few that seem obnoxious to contingencies of a peculiar nature. Such is the sympathetic powder; of which, not only many physicians, and other sober persons, have assured me, they had successfully made trial; but I have thought myself an eye-witness of its operation: and yet not only many have found it fail their expectation; but trying some of our own preparing, upon myself, I found it ineffectual, and unable to stop so much as a bleeding at the nose; yet upon application of it, a little before, we had seen such a bleeding, tho' violent, suddenly stop'd, in a person, who was so far from contributing, by his imagination, to the effect of the powder, that he derided those whom he saw apply it to some drops of his blood. That therefore, the sympathetic powder, and the weapon-salve, are never of any efficacy at all, I dare not affirm; but that they constantly perform what is promis'd of them, I must leave others to believe. Pioney-root has been much commended, both by antient and modern physicians, as an amulet against the falling-sickness; yet has it, by many, been found ineffectual. I have been apt to suspect, that its inefficacy might possibly proceed from having been unseasonably gather'd; and, when I was last in the west of *Ireland*, acquainting the most eminent *Galenist* there with my conjecture, he confirm'd me in it, by assuring me, that he had often try'd that root, unseasonably gather'd, without success: but having lately gather'd it under its proper constellation, as they speak, which is, when the decreasing moon passes under *Aries*; and ty'd it, being first slit, about the neck and arms of his patients; he had cured more than one, whom he named to me, of the epilepsy. Agreeably hereto, I find, that a famous physician of *Grenoble*,
Monsieur

Monfieur des Grands Prez, in the laft of his obfervations, communicated to the famous *Riverius*, folemnly profefles, he had, feveral times, freed his patients from the falling-ficknefs, by the fingle outward application of piony-roots, collected and apply'd, as above-mention'd. But, tho he thence infers the ufefulness of obferving the ftars in the practice of phyfic; yet, before much ftrefs be laid on fuch improbable notions, as are the moft of thofe of judiciary aftrologers, the influence of conftellations upon fimples, ought, by rigorous and competent experiments, to be better made out, than it hitherto has been.

But to leave contingent medicinal obfervations; I have obferv'd, even mathematical writers, to deliver fuch obfervations, as do not regularly hold true. For tho they claim it, as their privilege, and glory to affirm nothing, but what they prove by demonftration; and, tho they are ufually more attentive and exact, than moft other men, in making philofophical obfervations; yet the certainty and accuracy of what they deliver, muft be reftain'd to thofe purely mathematical ftudies, arithmetic and geometry; where quantity is abftractedly confider'd: for we are not to expect the fame accuracy, when they deliver obfervations of fuch things, wherein matter, and its properties, muft be confider'd. And, much lefs fhould this be expected, when they deliver obfervations made by the help of material inftruments, fram'd by the hands and tools of men. Many modern aftronomers have written of the *Maculae* and *Faculae* of the fun, fo, as to perfuade their readers, that fome of them are almoft constantly to be feen; and I am willing to think, that it was their having fo often met with fuch phenomena in the fun, that made them write as they did; yet, when I firft apply'd myfelf to the contemplation of thefe late discoveries, tho I wanted neither good telescopes, nor a dark room, to bring the image of the fun into; it was not till after a great while, and a multitude of fruitlefs obfervations, made at feveral times, that I could detect any of thefe fpo-
 ts, which have, during many months, appear'd fo much feldomer than, it feems, they did before, that I remember a moft ingenious profefor of aftronomy, excellently well furnifh'd with dioptrical glaffes, about that time complain'd to me, that for a very long while he had been unable to fee them. And as for the *Faculae*, that are written of as fuch ordinary phenomena, I muft profefs, that a multitude of obfervations, made with good telescopes, at feveral places and times, whilft the fun was spotted, has fcarce given me to fee, above once, the expected brightneffes.

And, as the nature of the material object, regarded by the mathematician, may thus deceive the expectations, ground-
 ed on what he delivers; fo, the like may happen, from the imperfection of the inftruments employ'd in the fenfible obfervations, whereon the mix'd mathematics depend. This is manifef in the difagreeing computations, that famous writers have given us of the circumference of the terreftrial globe; of the diftance, and magnitude, of the fixed ftars, and fome of the planets; nay, and of the height of mountains: which difagreement, as it may often proceed from the different method, and unequal skill of the feveral obfervers; fo, in many

The Usefulness of Philosophy.

cases, it may be imputed, to the greater or less exactness, and manageableness of the instruments employ'd. The great *Tycho Brahe*, who, besides his time and industry, has bestow'd vast sums on astronomical instruments, deserves to be heard on this occasion. "A small error," says he, "may be easily committed, even with the larger instruments; and if the situation and manner of using them be not wonderfully exact, abominable mistakes will be made. Besides all this, the instruments themselves, will, by use and time, degenerate: for, unless they be exquisitely made of solid metal, they will suffer changes from the air; and, unless they are large, the divisions thereon cannot be sufficiently exact. But in this case too, their weight and bulk are detrimental; so that hence they easily decline from the proper plane, or position, and grow unmanageable. And therefore, greater perfection is required in astronomical instruments, and greater skill to manage them, than has been hitherto generally taken notice of. This we have found by long practice and experience, and with no small cost and labour."

And as for the observations made at sea, *Fournier* advertises us, that upon trial of many instruments, both at sea and a-shore, no astronomer in the world, can be sure to make his observation at sea, within ten minutes of the precise truth. And, indeed, the observations of skilful mathematicians, may disagree so much, when they pretend to give us the determinate measures of things, that, of three very eminent moderns, who have taken upon them to determine, from experiments, the proportion betwixt air and water, the one makes not the weight of the latter to exceed that of the former above 150 times; whilst the other reckons water to be between 13 and 14 hundred times, and the third, no less than 10000 times, the heavier: not to mention a late famous writer or two, who have thought water, in comparison of the air, vastly under-reckon'd; even by this last estimate. And, we have made an experiment, relating to this subject, which, tho repeated several times in an hour, yet we fail'd twice as often as we succeeded in that time, without being able to know how the thing would prove before-hand, within some pounds weight.

Hence, then it appears, that those experiments should be several times very carefully try'd, upon which we mean to raise considerable superstructures, either theoretical or practical; and that it is unsafe to rely on single experiments, especially when minerals are concern'd: for many, to their cost, have found, that what they at first look'd upon as a happy mineral experiment, has prov'd; in the issue, the most unfortunate.

And this discourse may, also, serve as a kind of apology for sober experimental writers, in case, we should not always, upon trial, find the experiments and observations they deliver, answer our expectations. And, indeed, it would prove a great discouragement to wary and considerate naturalists, from enriching the world with their observations, if they should find, that their faithfulness, in setting down what they observ'd, is not able to protect them from the imputation of falshood; but that by publishing any thing for the good of others, they must expose their reputation to all the uncertainties whereto their experiments may prove obnoxious. 'Tis true

true, indeed, if a writer be fabulous, or a plagiarist, and delivers things, confidently, from hearsay; and his experiments, upon trial, succeed not; we may be allow'd to ascribe their unsuccessfulness rather to him, than to ourselves, or chance. But if an author, usually known to deliver things upon his own knowledge, and who shews himself careful not to be deceiv'd, and unwilling to deceive his readers, shall deliver any thing, as having try'd, or seen it, which, yet, agrees not with our experiments; 'tis a piece of equity to think, unless we have some manifest reason to the contrary, that he set down his experiment, or observation, as he made it; tho', for some latent reason, it does not constantly hold true.

Finding the Lord *Verulam* to deliver, that spirit of wine will swim upon oil of almonds, we immediately made trial of it; but, several times, found the oil to swim upon the spirit. Our tenderness, however, for the reputation of so great and candid a philosopher, made us think, that, possibly, he might have used spirit of wine more pure than ordinary; and, therefore, having provided some that was well rectified, the oil readily sunk therein, and lay quietly at the bottom. Thus, also, the learned Dr. *Brown* declaring, that *Aqua fortis* will quickly coagulate common oil, we put some of those liquors together, and let them stand, for a considerable space of time, in an open vessel, without finding any such change in the oil: but, being unwilling, that so candid and faithful a naturalist should suffer in his character, we, again, made the trial with fresh oil and *Aqua fortis*, in a long-neck'd vial, left open at the top; which we kept both in a cool place, and afterwards, in a digesting furnace: yet, after some weeks, we found no other alteration in the oil, than that it had acquir'd a high and lovely tincture. But, at length, suspecting our materials, we chang'd them; and, repeating the experiment, found, after some hours, the oil coagulated into the form of a whitish butter. And, perhaps, I may myself, on some occasions, stand in need of the like equity I have been careful to shew towards others. A very skilful chymist, by keeping salt in a vehement fire, for several days and nights together, and freeing the extracted liquor so carefully, both from its phlegm and terrestrial feces, prepar'd a spirit from it; wherewith, I must freely confess I dissolv'd crude gold: tho' I could not find, that the solutions I made of that metal were red, but, rather, of a yellow, or golden colour, much like those obtain'd by *Aqua regis*. But, neither this artist, nor I, have been able to make another spirit of salt, capable of dissolving gold, notwithstanding all the industry we have employ'd about it: which makes me refer this to contingent experiments; unless the prosperous event of our former trial may be ascrib'd to the quality of the salt distill'd, which was brought from the island of *Mayo*; where the scorching sun makes, out of the sea-water, a salt, that is accounted much stronger, and more spirituous, than that of *France*, and other more temperate climates. I once, also, instantly changed the colour of common oil, from a pale yellow, to a deep red, with a few drops of a liquor, that was almost colourless. But this experiment we have, several times, in vain, attempted to make again. And, therefore,

The Usefulness of Philosophy.

when I am satisfied of the abilities and circumspection of a writer, in delivering a matter of fact, upon his own knowledge, I do not, presently, reject his observation, as untrue, when it seems to be contradicted by a more undoubted observation, or to contradict a receiv'd and plausible hypothesis, or tradition: but, rather try if, by a proper distinction, or limitation, I can reconcile them; unless there appears some cause, that might lead him to mistake: for there sometimes happen irregularities, contrary to the usual course of things; as is evident in monsters; sometimes, the receiv'd hypothesis will not hold so universally as men presume; and sometimes, too, the contradiction betwixt the observations may be only imaginary, and so they may both be true.

That spiders are harmless in *Ireland*, is a known thing in that country; yet I dare not deny what the learned *Scaliger*, somewhere, affirms, that, in *Gascony*, their venom is so pernicious, that they, sometimes, poison those who tread upon them, thro' the very soles of their shoes. And, even here in *England*, some spiders are venomous, without biting.

It is generally taken for granted, that, under the same meridian, the magnetic needle keeps, every where, the same variation; whence many persons, upon reading the relations of the *Hollanders*, how, under the meridian, that passes by the island of *Corvo*, where the needle points directly to the poles, and which is, therefore, usually reckon'd the first meridian, they found, at about 46° of northern latitude, a declination of about 7 or 8° : and, again, at about 55° of latitude, a far greater number; and also, under the 20th parallel of southern latitude, in the same meridian of the *Azores*, 10 or 11° of declination; many persons, I say, if they should meet with these particulars, might suppose the *Dutch* to have been very bad observers, because such observations agree not with the theory of the needle's declination: yet, if we compare them with others of the like nature, made by good navigators, and skilful men, along other meridians; we may find cause, rather to rectify the general opinion, than reject the *Dutch* observations, for their disagreeing with it. The jesuit, *Jules Alenis*, (whom *Fournier* extols for the most accurate observer of the variation,) sailing to *China*, writes thus. "You must," says he, "take notice of one thing very considerable; namely, that the farther you go from the equator, in the same meridian, the greater you will find the magnetical variation."

To conclude, tho', in the western parts, it has been observ'd, that, generally, the inside of trees is harder than the outward part; yet, *Fournier*, who was very well vers'd in the subject, treating of the building of ships, gives it us, for a very important remark, that they have observ'd, at *Mar-seilles*, and all along the *Levant* shores, the wood, next the bark, to be stronger, than the heart of the tree.

But these things should not discourage us from the vigorous prosecution of our inquiries into nature; nothing we have said, can be interpreted to intimate more, than a great caution, in observing and relying on experiments. The physician does not renounce his profession, because many of his patients are not cured by his medicines; nor the husbandman forsake his

his plough, though, sometimes, an unseasonable storm, or flood, destroys his harvest ; because they both succeed oftner than they fail : so neither should we, by the contingencies incident to experiments, be deterr'd from making them ; because many are scarce ever obnoxious to casualties : and even among those, whose event is not so certain, we may, probably, make an experiment, very often, without meeting with any unlucky accident : and sure the prosperous success of many experiments, will well reward the pains employ'd on a few successless attempts. And here too, it not unfrequently happens, that, even when we obtain not what we seek, we find something as valuable. Thus merchants quit not their profession, because they, now and then, lose a vessel ; or, frequently, have their ships forc'd into different ports, from those they are bound for. And as the *American* navigators, employ'd by the *European* merchants, have, sometimes, by storms, been forc'd from their intended course, and driven upon unknown coasts, and made discoveries of new regions, much more advantageous to them, than the fairest winds, or most settled weather ; so, in philosophical trials, those unexpected accidents, that defeat our endeavours, sometimes cast us upon new discoveries, of much greater advantage than the desir'd success would have proved.



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T H E

P R E F A C E.

UNIVERSAL mechanics, or physics in general; which, in their full latitude, include whatever is knowable of the universe, and its parts; as they cannot be learnt, or taught at once, have, of necessity, been resolv'd into several distinct branches. Many of these branches have had particular names assign'd them; as, geography, astronomy, optics, chymistry, medicine, &c. But that part of natural knowledge, which falls directly under none of these grand heads, seems, in a more restrain'd sense, to be call'd philosophy, or physics. This, however, is a large part of universal philosophy; and appears capable of affording new branches of science, worthy of particular names; or of being join'd to some of the others; as the astronomy of comets has, of late, been added to that of the planets. And, even, the consideration of a single production of nature, or a very few properties of some bodies, may give rise to a new branch of knowledge. Thus, the load-stone has introduced magnetics; and the reflexivity, and refrangibility of the sun's rays, the doctrine of light and colours.

As new properties, therefore, come to be discover'd in bodies, universal mechanics will be enlarged, and increase in the number of its parts; till at length it becomes complete.

Hence it is, that so considerable a part of Mr. Boyle's works stands under the head of physics; for he discover'd abundance of new properties in bodies, which had been but little consider'd; at least, had not been mechanically consider'd, before his time.

The doctrine of the schools had then perverted philosophy, and render'd it unserviceable to mankind. But Mr. Boyle has abolish'd their chimerical substantial forms, and other useless and ill-grounded notions, by letting in more light upon them; and shewn us the true origin of qualities in bodies: and this he has done, by such well chosen experiments, that they may, at once, instruct, delight, and benefit the reader.

Indeed, Mr. Boyle appears to have been, in all respects, one of the most profitable authors, who ever treated philosophy. He is not content, barely, to gain his point, and firmly to establish the doctrine he advances; but is curious in the choice of the materials he employs to do it; and seldom produces an experiment, (of which, yet, he gives us a surprizing number) to confirm, or illustrate his assertions; but what may, some way or other, be made gainful to particular persons, and advan-

The PREFACE.

ageous to mankind, in general. This, evidently appears, in several of the following essays; as particularly, when he treats of forms, of colours, and of cold. His principal view in all his writings, seems to have been, to render them useful and instructive. He advances no barren theories, or deep abstract speculations; but lays down fertile principles, and proves and illustrates them by matters of fact, evident phenomena of nature, and apposite and fruitful experiments.

These experiments, 'tis true, are often taken from the laboratory; and require a little knowledge in chymistry, in order, fully, to understand and improve them. And it were greatly to be wish'd, that this art had a larger spread; and were more generally known, at least in its fundamental operations, and more obvious phenomena. The design of our author, in some of the following pieces, was to shew how advantageously chymistry, which, thro' ill management, had almost ruin'd philosophy, might be applied to the purposes of it. A design which the great Sir I. Newton has executed so far, as, by means of that art, to account for most of the operations of nature, in the smaller portions of matter; as, by a like sagacity, he has, with universal applause, solved the phenomena of the larger.

Thus much for the author; I must next say a word to the abridgment. I desire it may not be too hastily censur'd, if, in some of the following pieces, and particularly in the Origin of Forms, there is not that closeness of style observ'd, which we, at other times, employ; and which seems requisite in an abridgment. A greater latitude of expression was here made choice of, and some degrees of repetition admitted, in order to initiate and ground the less knowing, in the principles of the true philosophy, by making all things as plain and easy as possible. To have contracted the matter close, and never to have varied the manner of expression, would have render'd the doctrine less intelligible; and, consequently, less generally useful.

Under this head of physics, I have been obliged to admit a few pieces of Mr. Boyle, which, tho' properly philosophical, yet, treating of the great author of the universe, may, to some, appear of too religious a nature for the place assign'd them. But a very great philosopher assures us, that to treat of God from the phenomena of nature, is a part of experimental philosophy; and accordingly, at the close of the finest system of that philosophy, which was ever submitted to the human capacity, he has, from the phenomena of the world, discover'd more of its grand author, than we could, otherwise, have well hoped to know. And at the conclusion of another treatise of a beautiful branch of knowledge, he tells us, that, "if the whole system of philosophy shall, at length, be perfected, the bounds of moral philosophy will, also, be enlarged; for so far as we can know by natural philosophy, what is the first cause, what power he has over us, and what benefits we receive from him; so far our duty towards him, as well as that towards one another, will appear to us by the light of nature."

T H E

EXCELLENCE and GROUNDS

O F T H E

Mechanical Philosophy.

BY embracing the corpuscular, or mechanical philosophy, I am far from supposing, with the *Epicureans*, that, atoms accidentally meeting in an infinite vacuum, were able, of themselves, to produce a world, and all its phenomena : nor do I suppose, when God had put into the whole mass of matter, an invariable quantity of motion, he needed do no more to make the universe ; the material parts being able, by their own unguided motions, to throw themselves into a regular system. The philosophy I plead for, reaches but to things purely corporeal ; and distinguishing between the first origin of things, and the subsequent course of nature, teaches, that God, indeed, gave motion to matter ; but that, in the beginning, he so guided the various motion of the parts of it, as to contrive them into the world he design'd they should compose ; and establish'd those rules of motion, and that order amongst things corporeal, which we call the laws of nature. Thus, the universe being once fram'd by God, and the laws of motion settled, and all upheld by his perpetual concurrence, and general providence ; the same philosophy teaches, that the phenomena of the world, are physically produced by the mechanical properties of the parts of matter ; and, that they operate upon one another according to mechanical laws. 'Tis of this kind of corpuscular philosophy, that I speak.

And the first thing, that recommends it, is, the intelligibleness, or clearness, of its principles and explanations. Among the peripatetics, there are many intricate disputes about matter, privation, substantial forms, their productions, &c. And, the chymists are puzzled to give such definitions, and accounts, of their hypostatical principles, as are consistent with one another, and to some obvious phenomena : and much more dark and intricate, are their doctrines about the *Archeus*, astral Beings, and other odd notions ; which, perhaps, have, in part, occasion'd the darkness and ambiguity of their expressions, that could not be very clear, when their conceptions were obscure. And if the principles of the *Aristotelians*, and chymists, are thus obscure, it is not to be expected, that the explications, made by

PHYSICS. the help of such principles, only, should be intelligible. And, indeed, many of them are so general and slight, or otherwise so unsatisfactory, that, granting their principles, 'tis very hard to understand, or admit their applications of them to particular phenomena. And, methinks, even in some of the more ingenious and subtile of the peripatetic discourses, the authors, upon their superficial and narrow theories, have acted more like painters, than philosophers; and only shewn their skill, in making men fancy they see castles, cities, and other structures, that appear solid, magnificent, and extensive; when the whole piece is superficial, artificially made up of colours, and comprized within a frame. But, as to the corpuscular philosophy, men do so easily understand one another's meaning, when they talk of local motion, rest, magnitude, shape, order, situation, and contexture, of material substances; and these principles afford such clear accounts of those things, that are rightly deduced from them alone; that, even such peripatetics, or chymists, as maintain other principles, acquiesce in the explications made by these, when they can be had; and seek no further: tho, perhaps, the effect be so admirable, as to make it pass for that of a hidden form, or an occult quality. Those very *Aristotelians*, who believe the celestial bodies to be moved by intelligences, have no recourse to any peculiar agency of theirs, to account for eclipses: and, we laugh at those *East-Indians*, who, to this day, go out in multitudes, with some instruments, to relieve the distressed luminary; whose loss of light, they fancy, proceeds from some fainting fit; out of which, it must be rouz'd. For no intelligent man, whether chymist, or peripatetic, flies to his peculiar principles, after he is inform'd, that the moon is eclipsed, by the interposition of the earth, betwixt her, and it; and the sun, by that of the moon, betwixt him and the earth. And, when we see the image of a man, cast into the air, by a concave spherical speculum; tho most men are amazed at it, and some suspect it to be no less than an effect of witchcraft; yet he, who is skill'd enough in catoptrics, will, without consulting *Aristotle*, or *Paracelsus*, or flying to hypostatical principles, or substantial forms, be satisfy'd, that the phenomenon is produced by rays of light reflected, and made to converge, according to optical, and mathematical laws.

Few.

2. I next observe, that there cannot be fewer principles, than the two grand ones of our philosophy, matter, and motion; for matter, alone, unless it be moved, is wholly unactive; and, whilst all the parts of a body, continue in one state, without motion, that body will not exercise any action, or suffer any alteration; tho it may, perhaps, modify the action of other bodies, that move against it.

Primary.

3. Nor, can we conceive any principles more primary than matter and motion: for, either both of them were immediately created by God; or, if matter be eternal, motion must either be produced, by some immaterial supernatural agent; or, it must immediately flow, by way of emanation, from the nature of the matter it appertains to.

Simple.

4. There cannot be any physical principles more simple, than matter and motion; neither of them being resolvable into any other thing.

5. The

5. The next thing, which recommends the corpuscular principles, is, PHYSICS
 their extensiveness. The genuine, and necessary effect of the strong mo- And extensive
 tion of one part of matter, against another, is either to drive it on, in its en-
 tire bulk, or, to break and divide it into particles of a determinate motion,
 figure, size, posture, rest, order, or texture. The two first of these, for
 instance, are each of them capable of numerous varieties: for the figure of
 a portion of matter, may either be one of the five regular geometrical
 figures, some determinate species of solid figures, or irregular, as the
 grains of sand, feathers, branches, files, &c. And, as the figure, so the
 motion of one of these particles, may be exceedingly diversified, not only by
 the determination to a particular part of the world; but by several other
 things: as by the, almost, infinitely different degrees of celerity; by the
 manner of its progression, with, or without rotation, &c. and more yet
 by the line wherein it moves; as circular, elliptical, parabolical, hyperbolical,
 spiral, &c. For, as later geometricians have shewn, that these curves may
 be compounded of several motions, that is, describ'd by a body, whose mo-
 tion is mix'd, and results from two or more simple motions: so, how
 many more curves may be made by new compositions, and re-compositions
 of motion, is not easy to determine.

Now, since a single particle of matter, by virtue of only two mechanical
 properties, that belong to it, may be diversify'd so many ways; what a vast
 number of variations, may we suppose capable of being produced by the
 compositions, and re-compositions of myriads of single invisible corpuscles,
 that may be contain'd, and concreted in one small body; and each of them
 be endued with more than two or three of the fertile, universal principles
 above-mentioned? And the aggregate of those corpuscles, may be further
 diversify'd by the texture resulting from their convention, into a body;
 which, as so made up, has its own magnitude, shape, pores, and many ca-
 pacities of acting and suffering, upon account of the place it holds among
 other bodies, in a world, constituted like ours: so that, considering the
 numerous diversifications, that compositions and re-compositions may make
 of a small number; those, who think the mechanical principles may serve,
 indeed, to account for the phenomena of some particular part of natural
 philosophy, as statics, the theory of the planetary motions, &c. but prove
 unapplicable to all the phenomena of things corporeal; seem to imagine, that
 by putting together the letters of the alphabet, one may, indeed, make up all
 the words to be found in *Euclid* or *Virgil*, or in the latin or english language,
 but that they can by no means supply words to all the books of a great li-
 brary; much less, to all the languages in the world.

There are other philosophers, who, observing the great efficacy of
 magnitude, situation, motion, and connexion, in engines, are willing to
 allow those mechanical principles, a great share in the operations of bodies
 of a sensible bulk, and manifest mechanism; and, therefore, to be usefully
 employ'd, in accounting for the effects, and phenomena of such bo-
 dies: tho they will not admit, that these principles can be apply'd to the
 hidden transactions among the minute particles of bodies; and, therefore,
 think

PHYSICS. think it necessary to refer these to what they call nature, substantial forms, real qualities, and the like immechanical agents. But this is not necessary : for, the mechanical properties of matter, are to be found ; and the laws of motion take place, not only in the great masses, and the middle-siz'd lumps, but in the smallest fragments of matter : a less portion of it being as much a body, as a greater ; must as necessarily, as the other, have its determinate bulk and figure. And, whoever views sand thro' a good microscope, will easily perceive, that each minute grain, has as well its own size and shape, as a rock or a mountain. Thus too, when we let fall a large stone, and a pebble, from the top of a high building ; they both move conformably to the laws of acceleration, in heavy descending bodies : and the rules of motion are observ'd, not only in canon-bullets, but in small shot ; and the one strikes down a bird, according to the same laws, as the other batters a wall. And tho nature works with much finer materials, and employs more curious contrivances, than art ; yet an artist, according to the quantity of the matter he employs, the exigency of the design he undertakes, and the magnitude and shape of the instruments he uses, is able to make pieces of work, of the same nature or kind, of extremely different bulks ; where yet, the like art, contrivance, and motion, may be observed. Thus a smith, who, with a hammer, and other large instruments, can, out of masses of iron, forge great bars or wedges, to make strong and ponderous chains to secure streets and gates ; may, with lesser instruments, make smaller nails, and filings, almost as minute as dust ; and with yet finer tools, make links wonderfully light and slender. And, therefore, to say, that tho in natural bodies, whose bulk is manifest, and their structure visible, the mechanical principles may be usefully admitted ; but are not to be extended to such portions of matter, whose parts and texture are invisible, is like allowing, that the laws of mechanism may take place in a town-clock, and not in a pocket-watch : or, because the terraqueous globe is a vast magnetical body, one should affirm, that magnetical laws are not to be expected manifest in a small spherical piece of load-stone ; yet, experience shews us, that, notwithstanding the immense disproportion betwixt these two spheres, the terella, as well as the earth, hath its poles, equator, and meridians ; and, in several other magnetical properties, resembles the terrestrial globe.

When, to solve the phenomena of nature, agents are made use of, which, tho they involve no contradiction in their notions, as many think substantial forms and real qualities do ; yet are such, that we conceive not how they operate to produce effects ; such agents I mean, as the soul of the world, the universal spirit, the plastic power, &c. the curiosity of an inquisitive person is not satisfied hereby ; who seeks not so much to know, what is the general agent that produces a phenomenon, as by what means, and after what manner, it is produced. *Sennertus*, and other physicians, tell us of diseases, which proceed from incantation ; but sure, it is very trivial to a sober physician, who comes to visit a patient, reported to be bewitch'd, to hear only, that the strange symptoms he meets with, and
would

would have an account of, are produced by a witch, or the devil ; and he will never be satisfied with so short an answer, if he can, by any means, reduce those extravagant symptoms to any more known and stated diseases ; as epilepsies, convulsions, hysteric fits, &c. and if he cannot, he will confess his knowledge of this distemper, to come far short of what might be expected and attain'd in other diseases, wherein he thinks himself bound to search into the morbid matter ; and will not be satisfied, till he can, probably, deduce from that, and the structure of the human body, and other concurring physical causes, the phenomena of the malady. And, it would be but little satisfaction to one, who desires to understand the causes of the phenomena in a watch, and how it comes to point at, and strike the hours ; to be told, that a certain watch-maker so contriv'd it : or, to him who would know the true causes of an echo, to be answer'd, that it is a man, a vault, or a wood, that makes it.

I come now to consider that, which, I observe, most alienates other sects from mechanical philosophy ; viz. a supposition, that it pretends to have principles, so universal and mathematical, that no other physical hypothesis can be tolerated by it.

This, I look upon, as an easy, indeed, but an important mistake : for, the mechanical principles are so universal, and applicable to so many purposes, that they are rather fitted to take in, than to exclude, any other hypothesis founded on nature. And such hypotheses, if prudently consider'd, will be found, as far as they have truth on their side, to be either legitimately deducible from the mechanical principles, or fairly reconcileable to them. For such hypotheses will, probably, attempt to account for the phenomena of nature, either, by the help of a determinate number of material ingredients, such as the *tria prima* of the chymists ; or else by introducing some general agents, as the *Platonic* soul of the world, and the universal spirit, asserted by some chymists ; or, by both these ways together.

Now, the chief thing that a philosopher should look after, in explaining difficult phenomena, is not so much what the agent is, or does ; as, what changes are made in the patient, to bring it to exhibit the phenomena propos'd ; and by what means, and after what manner, those changes are effected. So that the mechanical philosopher being satisfied, one part of matter can act upon another, only by virtue of local motion, or, the effects and consequences thereof ; he considers, if the proposed agent be not intelligible and physical, it can never physically explain the phenomena ; and if it be intelligible and physical, it will be reducible to matter, and, some, or other, of its universal properties. And the indefinite divisibility of matter, the wonderful efficacy of motion, and the, almost, infinite variety of coalitions and structures, that may be made of minute and insensible corpuscles, being duly weigh'd ; why may not a philosopher think it possible, to make out, by their help, the mechanical possibility of any corporeal agent, how subtle, diffused, or active soever, that can be solidly proved to have a real existence in nature ? Tho the *Cartesians* are mechanical philosophers, yet their *Materia subtilis*, which the very name declares

PHYSICS. to be a corporeal substance, is, for ought I know, little less diffus'd thro' the universe, or less active in it, than the universal spirit of some chymists; not to say the *Anima mundi* of the *Platonists*. But whatever be the physical agent, whether it be inanimate, or living, purely corporeal, or united to an intellectual substance; the above-mention'd changes, wrought in the body, made to exhibit the phenomena, may be effected by the same, or the like means; or after the same, or the like manner: as, for instance, if corn be reduced to meal; the materials, and shape of the mill-stones, and their peculiar motion and adaptation, will be much of the same kind; and, to be sure, the grains of corn will suffer a various attrition, and comminution in their passage to the form of meal, whether the corn be ground by a water-mill, or a wind-mill, a horse-mill, or a hand-mill; that is, a mill, whose stones are turn'd by inanimate, by brute, or by rational agents. And if an angel himself, should work a real change in the nature of a body, 'tis scarce conceivable to men, how he could do it, without the assistance of local motion; since, if nothing were displac'd, or, otherwise mov'd than before, 'tis hardly conceivable, how it should be, in itself, different from what it was before.

But if the chymists, or others, who would deduce a compleat natural philosophy, from salt, sulphur, and, mercury, or any determin'd number of ingredients of things, would well consider what they undertake, they might easily discover, that the material parts of bodies can reach but to a few phenomena of nature, whilst these ingredients are consider'd but as quiescent things, whence, they would find themselves oblig'd to suppose them active; and that things, purely corporeal, cannot, but by means of local motion, and the effects that may result from it, be variously shap'd, siz'd, and combined parts of matter: so that the chymists must leave the greatest part of the phenomena of the universe unexplain'd, by means of the ingredients of bodies, without taking in the mechanical and more comprehensive properties of matter, especially local motion. I willingly grant, that salt, sulphur, and mercury, or some substances analogous to them, are obtainable, by the action of the fire, from a very great many diffusable bodies here below. Nor do I deny, that, in explaining several phenomena of such bodies, it may be of use to a naturalist, to know, and consider, that, as sulphur, for instance, abounds in the body propos'd, it may be, thence, probably argued, that the qualities, usually attending that principle, when predominant, may be, also, upon its account, found in the body that so largely partakes of it. But, tho' chymical explications are, sometimes, the most obvious, yet they are not the most fundamental, and satisfactory: for the chymical ingredient itself, whether sulphur, or any other, must owe its nature, and other qualities, to the union of insensible particles, in a convenient size, shape, motion, or rest, and texture; all which are but mechanical properties of convening corpuscles. And this may be illustrated by what happens in artificial fire-works. For, tho' in most of those sorts, made either for war, or recreation, gun-powder be a principal ingredient; and many of the phenomena may be deriv'd from the greater

greater or less proportion, wherein it enters the compositions: yet there may be fire-works made without gun-powder, as appears by those of the ancient *Greeks*, and *Romans*. And gun-powder owes its aptness to fire, and to be exploded, to the mechanical texture of more simple portions of matter, nitre, charcoal, and sulphur. And sulphur itself, tho' it be by many chymists mistaken for an hypostatical principle, owes its inflammability to the union of still more simple and primary corpuscles; since chymists confess, that it has an inflammable ingredient: and experience shews, that it very much abounds with an acid and unflammable salt, and is not destitute of a terrestrial part. It may, indeed, be here alledg'd, that the productions of chymical analyses, are simple bodies; and, upon that account, irresoluble. But, that several substances, which chymists call the salts, sulphurs, or mercuries of the bodies that afford them, are not simple and homogeneous, is demonstrable. Nor is their not being easily dissipable, or resolvable, a clear proof of their not being made up of more primitive portions of matter. For compounded bodies may be as difficultly resolvable, as most of those that chymists obtain by the fire: witness common green-glass, which is far more durable, and irresoluble, than many of those which pass for hypostatical substances. And some amels will, for several times, even vitrify in the forge, without losing their nature, or, often, so much as their colour: yet, amel consists of salt, powder of pebbles, or sand, and calcined tin; and, if not white, usually of some tinging metal, or mineral. But how indestructible soever the chymical principles are supposed, several of the operations ascribed to them, will never be made appear, without the help of local motion: were it not for this, we can but little better solve the phenomena of many bodies, by knowing what ingredients compose them, than we can explain the operations of a watch, by knowing of how many, and of what metals, the balance, the wheels, the chain, and other parts consist; or than we can derive the operations of a wind-mill, from barely knowing, that 'tis made up of wood, stone, canvas, and iron. And here let me add, that it would not, at all, overthrow the corpuscularian hypothesis, tho', either by more exquisite purifications, or by some other operations, than the usual analysis by fire, it should appear, that the material principles of mix'd bodies, are not the *tria prima* of the vulgar chymists; but, either substances of another nature, or fewer in number; or, if it were true, that the *Helmontians* had such a resolving menstruum, as their master's alkahest, by which, he affirms, that he could reduce stones into salt, of the same weight with the mineral; and bring both that salt, and all other mix'd and tangible bodies, into insipid water. For, whatever be the number or qualities of the chymical principles, if they really exist in nature, it may, very possibly, be shewn, that they are made up of insensible corpuscles, of determinate bulks and shapes: and, by the various coalitions, and textures of such corpuscles, many material ingredients may be composed, or made to result. But tho' the alkahestical reductions, newly mention'd, should be admitted, yet the mechanical prin-

ciples might well be accommodated even to them. For the solidity, taste, &c. of salt, may be fairly accounted for, by the stiffness, sharpness, and other mechanical properties of the minute particles, whereof salt consists: and if, by a farther action of the alkahest, the salt, or any other solid body, be reduced into insipid water, this, also, may be explain'd by the same principles; supposing a farther comminution of its parts, and such an attrition, as wears off the edges and points that enabled them to strike briskly upon the organ of taste: for as to fluidity, and firmness, they, principally, depend upon two of our grand principles, motion, and rest. And, 'tis certain, that the agitation, or rest, and the looser contact, or closer cohesion of the particles, is able to make the same portion of matter, at one time, a firm, and, at another, a fluid body. So that, tho' future sagacity, and industry of chymists, should obtain, from mix'd bodies, homogeneous substances, different in number, nature, or both, from their vulgar salt, sulphur, and mercury; yet the corpuscular philosophy is so general and fertile, as to be fairly reconcilable to such a discovery; and, also, so useful, that these new material principles will, as well as the old *tria prima*, stand in need of the more universal principles of the corpuscularians; especially of local motion. And, indeed, whatever elements, or ingredients, men have pitch'd upon; yet, if they take not in the mechanical properties of matter, their principles are so deficient, that I have observ'd, both the materialists and chymists, not only leave many things unexplain'd, to which their narrow principles will not extend; but, even in the particulars they presume to give an account of, they either content themselves to assign such common and indefinite causes, as are too general to be satisfactory; or, if they venture to give particular causes, they assign precarious or false ones, liable to be easily disproved by circumstances, or instances, whereto their doctrine will not agree. The chymists, however, need not be frightened from acknowledging the prerogative of the mechanical philosophy, since that may be reconcilable with the truth of their own principles, so far as they agree with the phenomena they are applied to: for these more confined hypotheses may be subordinate to those more general and fertile principles; and there can be no ingredient assign'd that has a real existence in nature, but may be deriv'd, either immediately, or by a row of compositions, from the universal matter, modified by its mechanical properties. For if with the same bricks, differently put together, and rang'd, several bridges, vaults, houses, and other structures may be rais'd merely by a various contrivance of parts of the same kind; what a great variety of ingredients may be produced by nature, from the various coalitions and contextures of corpuseles, that need not be suppos'd, like bricks, all of the same size and shape; but to have, both in the one and the other, as great a variety as could be wish'd for? And the primary and minute concretions, that belong to these ingredients, may, without opposition from the mechanical philosophy, be suppos'd to have their particles so minute, and strongly coherent, that nature, of herself, scarce ever tears them asunder. Thus mercury and gold may

be successively made to put on a multitude of disguizes; and yet so retain their nature, as to be reducible to their pristine forms.

From hence, it is probable, if, besides rational souls, there be any immaterial substances, such as the heavenly intelligences, and the substantial forms of the *Aristotelians*, that are regularly to be number'd among natural agents; their way of working being unknown to us, they can only help to constitute and effect things, but will very little help us to conceive how things are effected; so that, by whatever principles natural things are constituted, 'tis, by the mechanical principles, that their phenomena must be clearly explain'd. For instance, tho' we grant, with the *Aristotelians*, that the planets are made of a quintessential matter, and mov'd by angels, or immaterial intelligences; yet, to explain the stations, progressions, and retrogradations, and other phenomena of the planets, we must have recourse either to excentrics, epicycles, &c. or to motions made in elliptical, or other peculiar lines; and, in a word, to theories, wherein the motion, figure, situation, and other mathematical, or mechanical properties are chiefly employ'd. But, if the principles propos'd be corporeal, they will then be fairly reducible, or reconcilable to the mechanical principles; these being so general and fertile, that, among real material things, there is none but may be deriv'd from, or reduced to them. And when the chymists shall shew that mix'd bodies owe their qualities to the predominancy of any one of their three grand ingredients, the corpuscularians will shew, that the very qualities of this, or that ingredient, flow from its peculiar texture, and the mechanical properties of the corpuscles that compose it. And to affirm, that because the chymical furnaces afford a great number of uncommon productions, and phenomena, that there are bodies, or operations, amongst things purely corporeal, not derivable from, or reconcilable to the principles of mechanical philosophy; is to say, because there are many and various hymns, pavins, threnodies, courants, gavots, sarabands, &c. in a music book, many of the tunes, or notes, have no dependance on the scale of music; or as if, because excepting rhomboids, squares, pentagons, chiliagons, and numerous other polygons, one should affirm there are some rectilineal figures, not reducible to triangles, or that have properties which overthrow *Euclid's* doctrine of triangles, and polygons.

I shall only add, that as mechanical principles, and explanations, where they can be had, are, for their clearness, preferr'd by materialists themselves; so the sagacity and industry of modern naturalists, and mathematicians, having happily apply'd them to several of those difficult phenomena, which before were referr'd to occult qualities, 'tis probable, that when this philosophy is more scrutiniz'd, and farther improv'd, it will be found applicable to the solution of still more phenomena of nature. And 'tis not always necessary, that he who advances an hypothesis in astronomy, chymistry, anatomy, &c. be able, *a priori*, to prove it true, or demonstratively to shew that the other hypothesis, propos'd about the same subject, must be false; for, as *Plato* said, that the world is God's epistle to mankind; and

PHYSICS. might have added, in his own way, that it was written in mathematical characters; so, in the physical explanations of the parts and system of the world, methinks, there is somewhat like what happens, when men conjecturally frame several keys to read a letter written in cyphers. For tho one man, by his sagacity, finds the right key, it will be very difficult for him, either to prove, otherwise than by trial, that any particular word is not such as 'tis guess'd to be by others, according to their keys; or to shew, *à priori*, that theirs are to be rejected, and his to be prefer'd: yet, if due trial being made, the key he proposes be found so agreeable to the characters of the letter, as to enable one to understand them, and make coherent sense of them, its suitableness to what it should decypher, is, without either confutations, or foreign positive proofs, alone sufficient to make it accepted as the right key of that cypher. Thus, in physical hypotheses, there are some, that, without falling foul upon others, peaceably obtain the approbation of discerning men, only by their fitness to solve the phenomena for which they were devised, without thwarting any known observation, or law of nature: and therefore, if the mechanical philosophy shall continue to explain corporeal things, as it has of late, 'tis scarce to be doubted, but that, in time, unprejudiced persons will think it sufficiently recommended, by its being consistent with itself, and applicable to so many phenomena of nature.



THE
O R I G I N
O F
FORMS and QUALITIES;

Serving as an Introduction to the MECHANICAL PHILOSOPHY.

SECT. I.

THE doctrine I shall here attempt to establish, take as follows.

1. There is one universal matter, common to all bodies, an universal matter. extended, divisible, and impenetrable substance.

2. This matter being in its own nature but one, the diversity in bodies The necessity of motion. must necessarily arise from somewhat else; and since there could be no change in matter at rest, there is a necessity of motion to discriminate it; and for that motion, also, to have various tendencies.

Motion, in many parts of matter, appears manifest to sense; but how it came whence motion proceeds. by this motion, is disputed. The ancient corpuscularians, who acknowledged no author of the universe, were reduced to make it inherent in matter; and, consequently, coeval therewith: but since local motion, or an endeavour at it, is not included in the nature of matter, which is as much matter when at rest, as when in motion; and, since the same portion of matter, may from motion be reduced to rest; and, after it hath continued at rest, as long as other bodies do not put it out of that state, may, by external agents be moved again; I am of opinion, that the origin of motion in matter, is from God; as, also, the laws by which it operated in bringing the world to its present frame: so that local motion seems to be the principal amongst second causes, and the grand efficient of all that happens in nature. For tho' bulk, figure, rest, situation, and texture, concur to the phenomena of nature; yet, in comparison of motion, they seem, in many cases, to be effects, and in

PHYSICS. in others, little better than conditions or requisites, which modify the operation, that one part of matter, by virtue of its motion, hath upon another; as in a watch, the number, the figure, and correspondence of the wheels and other parts, are requisite to the performing the office of a watch; but, till these parts are actually put in motion, all their other properties remain inefficacious. Thus, also, a key, tho' it were too big or too little, or its shape unfit for that of the cavity of the lock, would not perform its office, tho' put into motion; yet, let its size and figure be never so fit, unless actual motion intervene, it will never lock or unlock: as, without the like actual motion, a knife, or razor, will not actually cut, how much soever their shape, and other qualities, fit them for that action. So brimstone, what disposition of parts soever it has to be turned into flame, would never be kindled, unless some actual fire, or other vehemently and variously agitated matter, puts the sulphureous corpuscles into a very brisk motion*.

Matter divi-
sible.

3. These two principles, matter and motion, being established, it will follow, that matter must be actually divided into parts; and that each of the primitive fragments, or other distinct and entire masses, must have two attributes, its own magnitude or size, and its own figure or shape. And, since experience shews, that this division of matter is frequently made into insensible particles; we may conclude, that the minutest fragments, as well as the largest portions of the universal matter, have, likewise, their peculiar bulk and shape. For being a finite body, its dimensions must be terminated, and measurable; and tho' it may change its figure, yet it will necessarily have some figure or other. We must, therefore, admit three essential properties of each entire part of matter, *viz.* magnitude, shape, and either motion or rest: the two first of which may be called inseparable accidents; because matter being extended, and yet finite, it is physically impossible, that it should be destitute of some bulk and determinate shape.

The notion of
real qualities
examined.

Whether these accidents may not be called the modes, or primary affections of bodies, to distinguish them from the less simple qualities, colours, tastes, &c. that belong to bodies upon their account; or whether, with the

* Motion is generally defin'd to be, the translation of a body from one place to another: but this translation, seems rather the effect of motion, than motion itself. Whatever is said to be in motion, may be consider'd, either with regard to the parts of immovable and infinite space; to the remote bodies that surround it; or to the surface of what is nearest to it. Now, as the parts of space are infinite and immovable, and have nothing in common with the alterations of matter; that change of situation, which respects the parts of space, without the least regard to the surrounding bodies, may properly be called absolute motion. Again, a body, said to be in motion, may be compared with bodies re-

mote: and, as a body may here be transfer'd, together with such as are near it; that change of situation, which is made with regard to bodies at a distance, may be termed common relative motion. In the last place, a body supposed in motion, may be compar'd with the surface of those bodies, which are very nery near it: and as in this case, the body may have neither an absolute, nor a common motion; and, what is thus at rest, may, in reality, have them both; we may call this change of situation, proper relative motion. See *Clarke Annot. in Robault. Physic. Ed. 3. p. 36—38. and Newton Princip. Ed. 2. p. 6—11.*

Epicureans, they may not be called the conjuncts of the smallest parts of matter, I shall not now consider. But the schools teach, that there are in natural bodies, many real qualities, and other real accidents, which not only are no modes of matter, but real entities distinct from it. Now, accident is, by logicians, used in two several senses: sometimes it is opposed to the fourth predicable, or property, and is then defined, "that which may be present or absent, without the destruction of the subject:" as a man may be sick or well, and a wall white or black; and yet the one be still a man, and the other a wall: and this, in the schools, is called *Accidens predicabile*, to distinguish it from what they call *Accidens predicamentale*, which is opposed to substance. And, as substance is commonly defined to be a thing, that subsists of itself, and the *substratum* of accidents; so an accident is said to be *id cujus esse est inesse*: and therefore *Aristotle*, who usually calls substances simply *ὄντα*, entities, most commonly calls accidents *ἐν τῷ ὄντι*, entities of entities; these requiring the existence of some substance wherein to reside, as in their subject of inhesion. And, because logicians make it the discriminating mark of substance from accident, that it cannot exist in another thing, as in its subject of inhesion, it is requisite to know, that, according to them, a thing is in a subject, which, however it be in another thing, is not in it as a part, and cannot exist separately from the thing wherein it is: as a white wall is the subject of inhesion of the whiteness we see in it; which same whiteness, tho' it be not in the wall as a part of it; yet cannot, according to our logicians, exist any where out of the wall, tho' many other bodies may have the like degree of whiteness. This premised, it will not be hard to discover the absurdity of the opinion, just mention'd, of real qualities and accidents; the school-doctrine about which, appears to be either unintelligible, or manifestly contradictory. For, speaking in a physical sense, if they will not allow these accidents to be modes of matter, but entities really distinct from it, and, in some cases, separable from all matter; they make them, indeed, accidents in name, but represent them under such a notion, as belongs only to substances: the nature of a substance consisting in this, that it can subsist of itself, without being in any thing else, as in a subject of inhesion: so that to tell us, a quality, or other accident, may subsist without a subject, is to allow it the true nature of substance. Nor could I ever find it intelligibly made out, what these real qualities are, that they deny to be either matter, or modes of matter, or immaterial substances. When a bowl is in motion or at rest, that motion or rest, or globular figure of the bowl, is not nothing, yet no part of the bowl; whose whole substance would remain, tho' it wanted any one of these accidents: and to make them real and physical entities, is, as if, because we may consider the same man sitting, standing, running, thirsty, hungry, &c. we should make each of these a distinct entity, as we give some of them distinct names: whereas, the subject of all these qualities is but the same man, considered with circumstances, which may make him appear different in one case, from what he appears in another. And, we must here observe, that not only diversity of names, but even diversity of definitions, does not always infer a diversity of physical entities in the subject

PHYSICS. *ject* whereto they are attributed. For it happens in many of the physical attributes of a body, as it does where a man, who is a father, a husband, a master, a prince, &c. may have a peculiar definition in each of these capacities; and yet the man, consider'd in himself, is but the same man, who, in respect of different capacities or relations to other things, is called by different names, which conclude not so many real and distinct entities in the person thus variously denominated.

The relative nature of physical qualities.

But because this notion may be of great importance to the nature of qualities; we may farther consider, that when the smith, who first invented locks and keys, had made his first lock, it was only a piece of iron, contrived into a particular shape; and when, afterwards, he made a key to it, that also, consider'd in itself, was nothing but a piece of iron of a determinate figure; but as these two pieces of iron might now be applied to one another, after a certain manner; and, as there was a congruity betwixt the wards of the lock, and those of the key, the lock and the key now, each of them, obtain'd a new capacity; and it became a principal part of the notion and description of a lock, that it was capable of being made to lock or unlock, by that other piece of iron we call a key; and it was look'd upon as a peculiar faculty and power in the key, to be fit to open and shut the lock: and yet, by these new attributes there was not added any real or physical entity, either to the lock or the key; each of them remaining the same piece of iron, just so shaped as it was before. And when the smith made other keys of different sizes, or with differing wards; tho' the first lock could not be opened with any of those keys, yet, that indisposition was nothing new in the lock, or distinct from the figure it had, before those keys were made. To carry this comparison a little further: tho' one, who had defined the first lock and the first key, would have done it by distinct definitions; yet, these definitions being given only upon account of certain respects, which the defined bodies had to one another, would not infer, that the two iron instruments physically differ'd, otherwise than in the figure, size, or contrivance of the iron, whereof each consisted. Thus, why may we not conceive, that as to those qualities which we call sensible, for instance, tho' by virtue of a certain congruity, or incongruity, in point of figure or texture, or other mechanical properties, to our senses, the portions of matter they modify are enabled to produce various effects, upon account whereof bodies are said to be endowed with qualities; yet, that they are not, in the bodies endowed with them, any real, or distinct entities, or differing from the matter itself, of such a determinate bigness, shape, or other mechanical modifications? And thus tho' the modern goldsmiths and refiners, reckon it amongst the most distinguishing qualities of gold, that it is dissoluble in *Aqua regia*, whilst *Aqua fortis* will not work upon it; yet these attributes are not, in the gold, any thing distinct from its peculiar texture; nor is the gold we have now of any other nature, than it was in *Pliny's* time, when *Aqua fortis* and *Aqua regia* were unknown. And if another menstruum, of which possibly I am possess'd, should be invented to dissolve pure gold in part, and change it into a different metalline body, there

there will then arise another new property, whereby to distinguish this from other metals : yet the nature of gold is not at all different now, from what it was before the discovery of this last menstruum. There are bodies neither cathartic nor sudorific, with some of which gold being joined, acquires a purgative virtue, and with others a power to procure sweat. Nature herself, sometimes produces things, that have new relations to others : and art, especially if assisted by chymistry, may cause so many new productions, that no man can tell, but the most familiar bodies may have multitudes of qualities, he dreams not of, which will hardly be imagined real physical entities. Beaten glass is commonly reckoned among poisons ; yet, its destructive faculty, supposed to be a peculiar entity in the beaten glass, is really nothing distinct from the glass itself, supposed of a determinate bigness and figure of parts, acquir'd by comminution. For these glassy fragments being numerous, rigid, small, and endowed with sharp points and cutting edges, are enabled, by these mechanical properties, to wound the tender membranes of the stomach and guts, and produce all the effects usually ascribed to some poisons : yet, the same is found to do no harm, where it is so finely powdered, as not to wound the intestines. Accordingly we see, that the fragments of sapphires, crystals, and rubies, things much harder than glass, are innocently used in cordial compositions ; being, by grinding, reduced to a powder too subtil to excoriate the stomach. Hence the multiplicity of qualities in the same natural bodies, may proceed from the bare texture, and other mechanical affections of their matter : for we must consider each body, not barely, as it is in itself, an entire and distinct portion of matter, but as a part of the universe ; and, consequently, placed amongst a great number and variety of other bodies, upon which it may act, and by which it may be acted upon several ways ; each whereof, men are apt to fancy a distinct power or quality in the body, whereby those actions, or in which those passions, are produced. We all know, that the sun hath a power to harden clay, soften wax, melt butter, thaw ice, turn water into vapour, make air expand itself in weather-glasses, contribute to blanch linen, render the white skin of the face swarthy, and mowed grass yellow, to ripen fruit, hatch the eggs of silk-worms, caterpillars, &c. and perform many other things, some of which seem contrary to others ; yet, these are not distinct powers or faculties in the sun, but only the productions of its heat, diversified by the different textures of the body it chances to work on, and the condition of the other substances concerned in the operation. And therefore, whether the sun, in some cases, has any influence at all distinct from its light and heat, we see that all the phenomena mention'd, are producible by the heat of common fire, duly applied and regulated. And, to give an instance of another kind ; having caused some solid balls of iron, skilfully hardened, and exquisitely shaped and glazed, to be purposely made, each of them proved a spherical looking-glass ; which, placed in the midst of a room, exhibited the images of the surrounding objects in a very regular and pleasing manner ; yet the globe endow'd with all these properties, was but iron reduced by the artificer to a spherical figure : and numerous *specula*, may be im-

PHYSICS.

diately made, by breaking a large drop of quick-silver into several little ones, each of which will serve for objects placed near it; and the smaller whereof, may, with a good microscope, afford a pleasant prospect of the neighbouring objects; tho' to reduce a parcel of stagnant quick-silver into many of these little spherical *specula*, whose properties are so differing from those of plain ones, there is nothing required, but a slight local motion, which, in the twinkling of an eye, changeth the figure of the self-same matter.

Texture another
genus.

4. And supposing all the universe annihilated, except any of the entire corpuscles, above-mention'd, it is hard to say, what could be attributed to it, besides matter, motion, rest, bulk, and shape: but there being now actually in the universe, great multitudes of corpuscles intermixed with one another, there arise in every distinct portion of matter, which a number of them make up, two new accidents; the one whereof more relates to each particular corpuscle, in regard to the stable bodies about it, namely, its posture: but when two or more such bodies are placed by one another, the manner of their being so placed, may be called their order. And when many corpuscles convene together, so as to compose any distinct body, as a stone or a metal; then, from their other accidents, (or modes) and from these two last mentioned, there arises a certain disposition, or contrivance of parts, in the whole, which we call the texture of it.

Sensible qualities
only relative.

5. And if we should conceive the universe to be annihilated, except one such body, suppose a metal, or a stone, it were hard to shew, that there is, physically, any thing more in it than matter, and the accidents already mentioned. But now we are to consider, that there actually are in the world, certain sensible and rational beings, called men; and the human body, having several of its external parts, as the eye, the ear, &c. each of a distinct and peculiar texture, whereby it is capable to receive impressions from the bodies about it, and, upon that account, called an organ of sense; we must observe, that these senses may be wrought upon by the figure, shape, motion, and texture of bodies without them, after several ways: some of those external bodies being fitted to affect the eye, others the ear, others the nostrils, &c. And to these operations of the objects on the senses, the mind of man, which, upon account of its union with the body, perceives them, gives distinct names; calling the one light, or colour, the other sound, the third odour, &c. And because, also, each organ of sense, as the eye, or the palat, may itself be differently affected by external objects, the mind, likewise, gives the objects of the same sense distinct appellations; calling one colour green, another blue; one taste sweet, and another bitter, &c. whence men have been induced to frame a long catalogue of such things, as, for their relation to our senses, we call sensible qualities. And, because we have been conversant with them before we had the use of reason; and because the mind of man is inclin'd to conceive almost every thing (even privations, as blindness, death, &c.) under the notion of a true entity, or substance; we have been, from our infancy, apt to imagine, that these sensible qualities are real beings in the objects they denominate; and have the faculty and power to work particular things; as gravity has a power to stop

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the motion of a bullet shot upwards, and carry that solid globe of matter towards the center of the earth: whereas, indeed, there is in the body, to which these sensible qualities are attributed, nothing real and physical, but the size, shape, and motion, or rest, of its component particles, together with that texture of the whole, which results from their being contrived as they are. Nor is it necessary they should have in them any thing more, like to the ideas they excite in us; those ideas being either the effects of our prejudices or inconsiderateness, or else to be derived from the relation that happens betwixt those primary accidents of the sensible object, and the peculiar texture of the organ it affects; as, when a pin, being run into the finger, causeth pain, there is no distinct quality in the pin, answerable to what we are apt to fancy in pain; but the pin, in itself, is only slender, stiff, and sharp, and by those qualities, happens to make a solution of continuity in the organ of feeling, upon which, by reason of the fabric of the body, and the intimate union of the soul with it, there ariseth that troublesome kind of perception, which we call pain.

6. But here a difficulty will arise; for since we explain colours, odours, and the like sensible qualities, by a relation to our senses; it seems evident, that they have an absolute being, independent of us: thus snow (for instance) would be white, and a glowing coal hot, tho' there were no man, or any other animal in the world: and it is plain, that bodies do not, by their qualities alone, affect our senses, but even inanimate things too; as a fire-coal will not only burn a man's hand, but would likewise heat wax, and thaw ice, tho' all the men, and sensitive beings in the world, were annihilated. To clear this difficulty, I do not say, there are no other accidents in bodies, than colours, odours, and the like; for it hath already been shewn, that there are more simple and primitive affections of matter, from which these secondary qualities proceed; and that the operations of bodies upon one another, result from the same, we shall see hereafter. Nor do I say, that all qualities of bodies are directly sensible, but observe, that when one body works upon another, the knowledge we have of their operation, proceeds either from some sensible quality, or some more general affection of matter; as motion, rest, or texture, generated or destroy'd in one of them: else it is hard to conceive, how we shall come to discover what passes betwixt them. And we must not look upon every distinct body, that affects the senses, as a bare lump of matter of the bigness, and external shape, it appears; many of them having their parts curiously contrived, and most of them, perhaps, in motion too. Nor must we suppose the universe that surrounds us, a moveless and undistinguish'd heap of matter, but a great engine; which, having either no vacuity, or none that is considerable betwixt its known parts, the actions of particular bodies upon one another, must not be barely estimated, as if two portions of matter, of their bulk and figure, were placed in some imaginary space beyond the world; but as being situate in the world, constituted as it now is, and consequently as having their action upon each other liable to be promoted, hindred, or modified by the actions of other bodies. A small force apply'd to move the index of a clock to the figure xii. will make

PHYSICS. the hammer often strike with force against the bell, and cause much more commotion among the wheels and weights, than a far greater force would do, if the texture and contrivance of the clock did not largely contribute to the production of such an effect. And in agitating water into froth, the whiteness would never be produced by that motion, were not the sun, or other lucid body, to shine upon that aggregate of small bubbles, and enable them confusedly to reflect numberless little, contiguous, lucid images to the eye. Thus, giving a concave figure to a large metalline speculum, would never enable it to fire wood, and to melt down metals, if the sun-beams were not, by means of that concavity, thrown to a point. And to shew, by an eminent instance, what various, and different effects, the same action of a natural agent may produce, according to the several dispositions of the bodies it works upon; in two eggs, the one prolific, the other not, the senses can, perhaps, find no difference before incubation; yet, these bodies, outwardly alike, so differ in the internal disposition of their parts, that if both be exposed to the same degree of heat; that heat will change the one into a putrid and fetid substance, and the other into a chick. Farther, I deny not, that bodies may be said to have those qualities, we call sensible, tho' there were no animals in the world: for a body, in that case, may differ, from those which are now quite destitute of quality, in having such a disposition of its constituent corpuscles, that in case it were duly apply'd to the organ of sense of an animal, it would produce such a sensible quality, which a body of another texture would not: thus, if there were no animals, there would be no such thing as pain; yet a pin may, upon account of its figure, be fitted to cause pain, in case it were moved against a man's finger; whereas a bullet, or other blunt body, moved against it with no greater force, would cause no such perception. Thus snow, tho', were there no lucid body, nor organ of sight in the world, it would exhibit no colour, hath a greater disposition than a coal, or foot, to reflect light, when the sun shines upon all three. And so a lute is in tune, whether it be actually plaid upon or no, if the strings be all so duly stretched, that it would appear to be in tune, in case it were touched. But, if a pin should be thrust into a man's finger, both a while before and after his death, tho' the pin be as sharp at one time as at the other, and makes in both cases a like solution of continuity; yet, in the former case, the action of the pin will produce pain, and not in the latter; because in this, the pricked body wants the faculty of perception: so, were there no sensitive beings, those bodies that are now the objects of our senses, would be disposed, indeed, to yield colours, tastes, and the like; but actually possess only those more genneral properties of bodies, figure, motion, texture, &c. To illustrate this farther: suppose a man should beat a drum at some distance from the mouth of a cave, conveniently situated to reflect the sound of it; tho' men will presently conclude, that cave to have an echo, and be apt to fancy upon that account, some real property in the place, to which the echo is said to belong; and tho' the same noise made in many of the neighbouring places, would not be reflected to the ear, and consequently manifest those places to have no echoes; yet,

to speak physically, this peculiar quality or property we fancy in the cave, is nothing but the hollowness of its figure, whereby it is so disposed, when the air beats against it, as to reflect the motion towards the place whence it began ; for here intervenes only the figure of one body, and the motion of another ; tho', if a man's ear chance to be in the way of these motions of the air, forwards and backwards, it gives him a perception of them, which he calls sound : and, because these perceptions, which are supposed to proceed from the same percussion of the drum, and thereby of the air, are made at distinct times one after another ; that hollow body, from whence the last sound appears to come to the ear, is imagined to have a peculiar faculty, upon account whereof we say, that such a place hath an echo. And tho' one body often seems to produce in another several such qualities as we call sensible, which therefore appear not to require any reference to our senses ; I consider, that when one inanimate body works upon another, there is nothing really produced by the agent in the patient, except some local motion of its parts, or some change of texture consequent upon that motion ; and so if the patient comes to have any sensible quality, that it had not before, it acquires it upon the same account with other bodies : and it is but a consequent to this mechanical change of texture, that by means of its effects upon our organs of sense, we are induced to attribute this or that sensible quality to it. As in case a pin should chance, by some inanimate body, to be driven against a man's finger, that which the agent doth, is but to put a sharp and slender body into such a kind of motion ; and that which the pin doth, is to pierce into the body it meets with, not hard enough to resist its motion : so that, upon this, there should ensue such a thing as pain, is but a consequent, that superadds nothing of real to the pin, which occasions that pain. Thus, if a piece of transparent ice be, by the fall of some hard body, broken into a gross powder that looks whitish, the falling body doth nothing to the ice, but break it into very small fragments, that lie confusedly upon one another ; tho' by reason of the fabric of the world, and of our eyes, there will, in the light, ensue, upon this comminution, such a kind of plentiful reflection of the incident rays to our eyes, as we call whiteness : and when the sun, by thawing this broken ice, destroys the whiteness of that portion of matter, and makes it transparent, which it was not before, it only alters the texture of the component parts, by putting them into motion, and thereby into a new order ; in which, by reason of the disposition of the pores intercepted betwixt them, they reflect but few of the incident rays of light, and transmit the greater part. Thus when a rough piece of silver is burnished, that which is really done, is but the depression of the little protuberant parts into one level with the rest of the superficies ; tho' upon this mechanical change of the texture of the superficial parts, we say, that it hath lost the quality of roughness, and acquir'd that of smoothness, because the little extancies, by their figure, before resisted, a little, the motion of our fingers, and grated upon them, when now the fingers meet with no such resistance. It is true, the fire thaws ice, and also makes wax flow, and enables it to burn a man's hand ; yet this doth not necessarily argue any inhe-

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PHYSICS. rent quality of heat in it, distinct from the power it hath of putting the small parts of the wax into such a motion, as makes their agitation surmount their cohesion; which motion, together with their gravity, is enough to make them, for a season, constitute a fluid. *Aqua fortis*, without any sensible heat, will give camphire the form of a liquor distinct from itself; as a strong fire will, also, make camphire fluid. And I know a liquor, into which certain bodies being put, when both itself and they are actually cold, will not only speedily dissipate many of their parts into smoak, but leave the rest black, and burnt almost like a coal. So that, tho' we suppose the fire to do no more, than variously and briskly agitate the insensible parts of wax; this may suffice to make us think the wax endowed with a quality of heat; because, if such an agitation be greater than that of our organs of touch, 'tis enough to produce in us the sensation we call heat; which is so much a relative to those organs, that we see the same luke-warm water, whose corpuscles are only moderately agitated by the fire, will appear hot to one hand, if that be very cold, and cold to the other, in case that be very hot, tho' both of them belong to the same man. In short, if we fancy any two of the bodies about us, to have nothing to do with any other body in the universe, it is not easy to conceive, either how one can act upon the other, but by local motion, or how by motion it can do any more, than put the parts of the other body into motion too, and thereby produce in them a change of situation and texture, or of some other of its mechanical affections: tho' this passive body, being placed among others, in a world constituted as ours is now, and being brought to act upon the most curiously contriv'd organs of animals, may, upon both these accounts, exhibit many different phenomena; which, tho' we look upon them as distinct qualities, are but the effects of the universal properties of matter; and may be deduced from the size, shape, motion, (or rest) posture, order, and the resulting texture of its insensible parts. And therefore, tho' for shortness, I shall not scruple to use the word, qualities; since it is already generally received, I must be understood to mean it in a sense suitable to this doctrine*.

Form, what.

7. We may next consider, that men having taken notice of certain accidents associated in some bodies, and other conventions of accidents in others, they, for conveniency, and the more expeditious expression of their conceptions, agreed to distinguish them into several sorts; which they call genders, or species, according as they referred them, either upwards to a more comprehensive sort of bodies, or downwards to a narrower species, or to individuals. Thus, observing many bodies to agree in being fusible, malleable, heavy, &c. they gave to that sort of body the name of metal; which is a genus, in reference to gold, silver, lead, and but a species in reference to that sort of mix'd bodies call'd fossils; this superior genus comprehending both metals, stones, and other concretions, though itself

* For a more full account of this matter, see Mr. Locke's Essay on human understanding, from book 2. ch. 23. to book 3. ch. 5.

be but a species in respect of mix'd bodies. Now, when a body is referr'd to any particular species; because men have agreed to signify all the essentials requisite to constitute such a body, by one name, most writers have been apt to think, that, besides the common matter of all bodies, there is but one thing that discriminates it from other kinds, and makes it what it is; and this, for brevity-sake, they call form; which, because all the qualities, and other accidents of the body, must depend on it, they also imagine to be a very substance, and, indeed, a kind of soul, that, united to the gross matter, with it composes a natural body, and acts by the several qualities, to be found therein, which men usually ascribe to the creature so composed. But ask a man what gold is, if he cannot shew you a piece, and tell you this is gold, he will describe it as a body that is extremely ponderous, very malleable, ductile, fusible, yet fixed in the fire, and of a yellowish colour; and if you offer to put off to him a piece of brass for a piece of gold, he will presently refuse it; and tell you, that, though your brass be colour'd like that, it is not so heavy, so malleable, nor will, like gold, resist the fire, or *Aqua fortis*. And if you ask men, what they mean by a ruby, nitre, or a pearl, they will still make you such answers, from whence you may clearly perceive, that whatever we talk, in theory, of substantial forms, yet that, upon account of which, we really distinguish any one body from another, and refer it to this or that species of bodies, is nothing but an aggregate or convention of such accidents, as most men, by a kind of agreement, think necessary, or sufficient to make a portion of the universal matter belong to a determinate genus or species of natural bodies. The maintaining it possible to transmute the ignobler metals into gold, argues, that if a man could bring any parcel of matter to be yellow, malleable, ponderous, and to have a concurrence of all those accidents, by which men try true gold from false, they would, without scruple, take it for true gold. And, indeed, since to every determinate species of bodies, there belongs more than one quality, there needs no more sufficiently to discriminate any one kind of bodies, from all others in the world, not of that kind. Tho' spheres and parallelopipeds differ but in shape, yet this difference alone is the ground of so many others, that *Euclid*, and other geometricians, have demonstrated many properties of the one, which in no wise belong to the other. And it would be thought a man's own fault, if he could not distinguish a needle from a file, or a key from a pair of scissars; tho' these being all made of iron, and differing but in bigness and shape, are less remarkably unlike, than natural bodies; the most part of which differ from each other in many more accidents than two. Nor need we think, that qualities being but accidents, they cannot be essential to a natural body: for accident is sometimes opposed to substance, and sometimes to essence; and tho' an accident can be but accidental to matter, as it is a substantial thing, yet it may be essential to a particular body; as tho' roundness is but accidental to brass, yet it is essential to a brass sphere; because, tho' the brass were destitute of sphericity, it would still be a corporeal substance; yet, without that roundness, it could not be

PHYSICS. a sphere : wherefore, since an aggregate of qualities is enough to make the portion of matter, wherein it is found, what it is, and denominate it of a determinate sort of bodies ; and since those qualities themselves, proceed from the more primary and universal affections of matter, *viz.* bulk, shape, motion, or rest, and the texture thence resulting ; why may not the form of a body, made up of those qualities, united in one subject, likewise consist in such a convention of the mechanical properties of matter, as is necessary to constitute a body of that determinate kind ? And so, though I shall, for brevity-sake, retain the word form ; yet I would be understood to mean by it, not a real substance, distinct from matter, but only the matter itself of a natural body, consider'd with its peculiar manner of existence ; which, I think, may be properly call'd, either its specific or denominating state, or its essential modification ; or, to express it in one word, its stamp : for such a convention of accidents, is sufficient to perform the offices necessarily required in what men call a form ; since it renders the body what it is, making it appertain to a determinate species, and discriminating it from all other species of bodies whatsoever. It is, I know, said by some, that the form of a body ought to be the principle of its operation ; and we shall hereafter consider, in what sense this is to be admitted, or rejected. In the mean time, it may suffice, that even the vulgar philosophy acknowledges, that natural things, for the most part, operate by their qualities ; and how great the power may be, which a body can exercise by virtue of a single quality, will appear by the various effects which fire produces by its heat. And if several active qualities convene in one body, (as that which I mean by form, usually comprizes several of them) how great things may be thereby performed, might be guess'd from what we see done with some engines, by virtue of those accidents, the shape, size, motion, and contrivance of their parts. But, besides such operations, as proceed from the essential modification of the matter of the body, consider'd as one intire corporeal agent, it may, in several cases, have other operations, upon account of those particular corpuscles, which, tho' they concur to compose it, and are, in regard of the whole, consider'd but as its parts, may yet retain their own particular nature, and many peculiar qualities. Thus in a watch, besides the office it performs as such, the several parts whereof it consists, as the spring, the wheels, the string, &c. may have each its peculiar bulk, shape, and other attributes ; upon account of one or more of which, the wheel, spring, &c. may do other things, than what it merely performs as a constituent part of the watch. And so in the milk of a nurse, who hath taken a potion some hours before she gives suck ; tho' the corpuscles of the purging medicine appear not, to sense, distinct from the other parts of the milk, which, in far greater numbers, concur with them, to constitute that white liquor ; yet these purgative particles, that seem to be but part of the matter whereof the milk consists, so far retain their own nature, and qualities, that, being sucked in with the rest, by the infant, they quickly discover themselves by purging him.

8. It remains that we declare, what is to be meant by generation, corruption, and alteration. In order whereto, we may consider; first, that there are in the world numberless particles of matter, each of which is too small to be singly sensible; which, being intire and undivided, must needs both have its determinate shape, and be very solid; so that, tho' it be mentally divisible, yet, by reason of its smallness, and solidity, nature scarce ever actually divides it: and such particles might, in this sense, be called *minima*, or *prima naturalia* *. Secondly, there are also multitudes of corpuscles, which are made from the coalition of several of the former *minima naturalia*, whose bulk is so small, and their adhesion so close, that each of these little primitive concretions, or clusters of particles, is singly below the discernment of sense; and tho' not absolutely indivisible by nature into the *prima naturalia* that composed it, or, perhaps, into other little fragments; yet they very rarely happen to be actually dissolved, or broken; but remain intire in a great variety of sensible bodies, and under various forms, or disguises. Thus, even grosser and more compound corpuscles, may have such a permanent texture: for quick-silver may be turned into a red powder, a malleable body, or a fugitive smook; and disguised by many other ways, and yet remain true and recoverable mercury. And these are, as it were, the seeds, or immediate principles of many sorts of natural bodies; viz. earth, water, salt, &c. and, tho' singly insensible, they become capable, when united, to affect the sense. If good camphire be kept a while in pure spirit of wine, it will be thereby reduced into such little parts, as totally to disappear in the liquor, without making it less clear than fair water; yet, if into this mixture, you pour a competent quantity of water, in a moment the scatter'd corpuscles of the camphire will, by re-uniting themselves, become white, and visible, as before. Thirdly, as well each of the *minima naturalia*, as each of the primary clusters, having its own determinate bulk and shape, it must always happen, when these come to adhere to one another, that the size, and often, that the figure of

* "It seems probable to me," says Sir Isaac Newton, "that God, in the beginning, formed matter into solid, massy, hard, impenetrable, moveable particles, of such sizes and figures, and with such other properties, and in such proportion to space, as most conduced to the end for which he formed them; and that these primitive particles, being solids, are incomparably harder than any porous bodies compounded of them; even so hard, as never to wear, or break in pieces; no ordinary power being able to divide what God himself made one in the first creation. While these particles continue entire, they may compose bodies of one and the same nature, and texture, in all ages: but should they

"wear away, or break in pieces, the nature of things depending on them would be changed. Water and earth, composed of old worn particles, and fragments of particles, would not be of the same nature and texture now with water and earth, composed of entire particles in the beginning. And therefore, that nature may be lasting, the changes of corporeal things are to be placed only in the various separations, and new associations and motions of these permanent particles; compound bodies being apt to break, not in the midst of solid particles, but where these particles are laid together, and only touch in a few points." Newton. Optic. p. 375, 376.

PHYSICS.

the corpuscle, compos'd by their juxtaposition and cohesion, will be changed; and not seldom too, the motion of the one, the other, or both, will receive a new tendency, or be alter'd as to its velocity, or otherwise: and the like will happen, when the corpuscles, that compose a cluster of particles, are disjoined, or part of the little mass is broken off. And, whether any thing of matter be added to a corpuscle, or taken from it, in either case the size of it must necessarily be altered, and, for the most part, the figure will be so too; whereby it will both acquire a congruity to the pores of some bodies, and become unfit for those of others; and consequently be qualified to operate on several occasions, much otherwise than before. Fourthly, when many of these insensible corpuscles come to be associated into one visible body, if most of them be put into motion, from what cause soever the motion proceeds, that itself may produce great changes, and new qualities in the body they compose: for motion may do this even when it makes no visible alteration in the body; as air put in a current, acquires a new name, and is called wind, and, to the touch, appears far colder, than the same air, not formed into a stream; and iron, by being briskly rubbed against wood, or other iron, hath its small parts so agitated, as to feel hot. This motion, also, frequently makes visible alterations in the texture of the body, into which it is received; for the moved parts always endeavour to communicate their motion, or some degree of it, to parts, which before were either at rest, or otherwise moved; and, often, the same moved parts thereby either disjoin, or break some of the corpuscles they hit against; and so change their bulk, or shape, or both; and either drive some of them quite out of the body, and, perhaps, lodge themselves in their places, or else associate them with others anew; whence it usually follows, that the texture is, for a while at least, much altered. Thus water, by losing the wonted agitation of its parts, acquires the firmness and brittleness we find in ice; and wants much of the transparency it had when fluid. Thus, also, by very hard rubbing two pieces of resinous wood against one another, we may make them throw off many of their looser parts into steams, and visible smoke; and, if the attrition be duly continued, cause that commotion so to change the texture of the whole, as afterwards to turn the superficial parts into a kind of coal. And milk, especially in hot weather, will, by the intestine languid motions of its parts, be, in a short time, turned into a thinner sort of liquor, and into cream; the latter whereof, will, by being barely agitated, soon turn into that unctuous and consistent body we call butter, and into a thin, fluid, and sour liquor. In like manner, by bruising fruit, its texture is commonly so changed, that the bruised part soon becomes of a different nature from the sound; and of another colour, taste, smell, and consistence. So that local motion hath, of all other affections of matter, the greatest share in the alteration and modification thereof; since it is not only the grand efficient among second causes, but is also, frequently, one of the principal things, that constitutes the form of bodies; as when two sticks are fired by long and vehement attrition, local motion is not only that which kindles the wood, and so, as an efficient, produces the fire, but that, which principally concurs

curs to give the produced stream of shining matter the name and nature of flame; and thus it, likewise, concurs, to constitute all fluid bodies. Fifthly, Since it is from the size, shape, and motion of the small parts of matter, and the texture that results from the manner of their being disposed in any body, that the colour, odour, taste, and other qualities of that body, are to be derived; it will be easy to judge such changes possible, as may account for the generation and corruption of bodies, from the convention, dissolution, and the alterations of them, by the transposition of their constituent particles.

And hence will easily flow the doctrine of generation, corruption, and alteration. For if in a parcel of matter there happen such a concurrence of all those accidents, as men, by tacit agreement, have thought necessary and sufficient to constitute any one determinate species of things; then a body belonging to that species is generated *de novo*. Not that there is, really, any thing substantial produced, but that those parts of matter, which, indeed, pre-existed in other dispositions, are now brought together after a manner, requisite to entitle the body, which results from them, to a new denomination, and make it appertain to such a determinate species of natural bodies; so that no new substance is produced in generation, only that, which was pre-existent, obtains a new modification, or manner of existence. Thus, when the spring, wheels, string, balance, index, &c. necessary to a watch, are set together in the order requisite to make such a little engine as shall mark the hours, a watch is said to be made; tho' none of the parts are produced anew, but till then the divided matter was not contrived and put together, in the manner requisite to constitute the thing we call a watch. And so, when sand and ashes are well melted together, and suffered to cool, there is generated, by the colliquation, that sort of concretion, we call glass; tho' its ingredients were both pre-existent, and do, but by their association, obtain a new manner of existing together. And, as a body is said to be generated, when it first appears clothed with all those qualities, upon account whereof men call some bodies stones, others metals, others salts, &c. so when a body comes to lose all or any of those accidents that are essential, and necessary to constitute such a body, it is then said to be corrupted or destroy'd; and is no more a body of that kind, but loses the title to its former denomination; tho' nothing corporeal or substantial perishes in this change, only the essential modification of the matter is destroy'd; and tho' the body be still a body, yet it is no longer such a body as before, but perisheth in the capacity of a body of that kind. Thus, if a stone, falling upon a watch, break it to pieces; as, when the watch was made, there was no new substance produced, all the material parts being pre-existent somewhere or other; so, not the least part of the substance of the watch is lost, but only displaced and scattered; yet that portion of matter ceaseth to be a watch. Thus, when ice comes to be thawed in close vessels, tho' the corruption be produced only (for ought appears) by introducing a new motion and disposition into the parts of the frozen water, yet it thereupon ceaseth to be ice, tho' it remains as much water, and, consequently, as much a body, as before it was frozen,

PHYSICS. or thawed. These, and the like examples, will teach us how to understand that common axiom of naturalists, *corruptio unius est generatio alterius*, & *contra*; for, since it is acknowledged on all hands, that matter cannot naturally be annihilated; and, since there are some properties, as size, shape, motion, &c. that are inseparable from the actual parts of matter; since also the coalition of any competent number of these parts is sufficient to constitute a natural body, endowed with several sensible qualities; the same agents, that shatter the frame, and destroy the texture of one body, will, by shuffling them together, and disposing them after a new manner, necessarily bring them to constitute some new sort of bodies: as the same thing, that, by burning, destroys wood, turns it into flame, soot, and ashes. Only I doubt, whether the axiom holds generally true, if it be meant, that every corruption must end in the generation of a body, belonging to some particular species of things, unless we take powders and fluid bodies, indefinitely, for species of natural bodies; since it is plain, there are multitudes of vegetables, and other concretions, which, when they rot, do not turn into worms, but either into some slimy or watry substance, or else crumble into a kind of dust or powder, which, tho' esteemed the earth, whereinto rotten bodies are, at length, resolved, is very far from being of an elementary nature, but as yet remains a compound body, retaining some qualities; whence, often, the dust of one sort of plant, or animal, differs much from that of another.

To this account of the corruption of bodies, we may add, that their putrefaction is but a peculiar kind of slow corruption, which happens to them, for the most part, by means of the air, or some other ambient fluid, penetrating their pores, and, by its agitation, changing the texture, and, perhaps too, the figure of the corpuscles that compose them; whence the body, thus changed, acquires qualities unsuitable to its former nature, and, generally, offensive to our senses. For I observe, that medlars, tho' they acquire, in length of time, the colour and softness of rotten apples, and other putrefied fruit; yet, because their taste is not then harsh as before, we call that ripeness in them, which otherwise we should call rottenness. And tho' upon the death of a beast, we generally call that change, which happens to the flesh or blood, putrefaction; yet we say not so of what happens to those parts of the same animal, whereof musk is made, because that has a grateful scent. And we see, that some men, who are pleased with rotten cheese, think it not to have degenerated, but to have now attained its best state. But as a body seldom acquires, by generation, no other qualities, than just such as are absolutely necessary to rank it in the species that denominates it; there are in most bodies several other qualities, that may be present or absent without essentially changing the subject: thus water may be clear or muddy, sweet or fetid, and still remain water; butter may prove white or yellow, sweet or rancid, consistent or fluid, and still be butter. Whenever, therefore, a parcel of matter acquires or loses a quality, that is not essential to it, that acquisition or loss is distinctly called alteration; and even generation and corruption, according to this doctrine, are but several kinds of alteration, taken in a large sense.

And

And here we may take notice of the fertility and extent of the mechanical hypothesis; for since, according to our doctrine, the world we live in, is not a moveless or indigested mass of matter, but an engine, wherein the greatest part of the common matter of all bodies is always in motion; and wherein bodies are so close set by one another, that they have either no vacuities betwixt them, or but few and very small ones; and since, according to us, the various manner of the coalition of several corpuscles into one visible body, is enough to give them a peculiar texture, and thereby fit them to exhibit many sensible qualities, and to become a body, sometimes of one denomination, and sometimes of another; it will naturally follow, that from the various occurrences of those innumerable swarms of little bodies, that are moved about in the world, there must be many fitted to stick to one another, and so compose concretions; many disjoined from one another, and agitated apart; and multitudes also, that will be driven to associate themselves, now with one body, and again with another. And, if we, also, consider on the one side, that the sizes of the small particles of matter may be very various, and their figures almost innumerable; that if a parcel of matter happen to stick to one body, it may chance to give it a new quality; and, if it adhere to another, or hit against some of its parts, constitute a body of a new kind; or, if a parcel of matter be struck off from another, it may barely, by that, leave it, and itself become of a different nature from that it had before: if, I say, we consider these things, it will not be hard to conceive, that there may be an incomprehensible variety of associations and textures of the minute parts of bodies, and consequently, a vast multitude of portions of matter endowed with many different qualities deserving distinct appellations; tho' for want of care and proper words, men have not yet taken so much notice of their less obvious varieties, as to sort them, as they deserve, and give them distinct and proper names. So that tho' I would not say, any thing may immediately be made of every thing, as a gold ring of a wedge of gold, or oil, or fire, of water; yet, since bodies having but one common matter, can be differenced but by accidents, which seem, all of them, the effects and consequents of local motion, 'tis not absurd to think, that by the intervention of some very small addition or subtraction of matter, and of an orderly series of alterations, gradually disposing the matter to be transmuted, almost any thing may, at length, be made of any thing; as, tho' out of a wedge of gold, one cannot immediately make a ring, yet by either wire-drawing that wedge, by degrees, or by melting it, and casting a little of it into a mould, the thing may be effected. And so, tho' water cannot immediately be transmuted into oil, much less into fire, yet if you nourish certain plants with water alone, till they have assimilated a great quantity of it into their own nature, you may, by committing this transmuted water to distillation, in convenient glasses, obtain, besides other things, much of a true oil, and a black combustible coal*.

What

* Sir Isaac Newton seems to be of opinion, | the finest of bodies, light. " The changing
that even gross bodies are convertible into | " of bodies into light, and light into bodies,
" is,

PHYSICS.

Recapitulation.

What we would prove, is, at length, this; first, that the matter of all natural bodies is a substance extended and impenetrable. That all bodies thus agreeing in the same common matter, their distinction is to be taken from those accidents which diversify it. That motion, not being essential to matter, and not originally producible by other accidents, as they are from it, may be look'd upon as the first and chief mode or affection of matter. That motion, variously determined, naturally divides the matter, it belongs to, into actual fragments; and this division, obvious experience manifests to have been made into parts exceedingly minute, and very often too minute to be singly perceivable by our senses. Whence it necessarily follows, that each of these minute parts, or *minima naturalia*, (as well as every particular body, made up by the coalition of any number of them) must have its determinate size, and shape; and that these three, bulk, figure, and either motion or rest, are the primary and most universal modes of the insensible parts of matter, consider'd each of them apart. That when several of them are consider'd together, there will necessarily follow, both a certain position and posture in regard to the horizon, and a certain order before, behind, or a-side of one another; and when many of these small parts convene into one body, from their primary affections, and their disposition or contrivance as to posture and order, there results what we call the texture of that body. And these are the affections that belong to a body, consider'd in itself, without relation to sensitive beings, or to other natural bodies. We would further shew, that there being men in the world, whose organs of sense are so differently contrived, that one is fitted to receive impressions from some, and another from other sorts of external objects; the perceptions of these impressions are differently express'd by words, as heat, colour, sound, odour; and are commonly imagined to proceed from certain distinct and peculiar qualities in the external object, bearing a resemblance to the ideas, which their action upon the senses excites in the mind; tho' all these sensible qualities, and the rest to be met with in the bodies without us, are but the effects or consequences of the primary affections of matter, whose operations are diversified according to the nature of the organs, or other bodies they affect. That when a portion of matter, either by the access or recess of corpuscles, or by the transposition of those it consisted of before, or by any two or all of these ways, obtains a concurrence of all the qualities men commonly agree to be necessary and sufficient to denominate the body possess'd of them, a metal, a stone, or the like, and to rank it in any peculiar and determinate species of bodies; then a body of that denomination is said to be generated. And

" is," says that great philosopher, " very
 " conformable to the course of nature,
 " which seems delighted with transmuta-
 " tions. Water, which is a very fluid,
 " tasteless salt, she changes by heat into
 " vapour, which is a sort of air; and by
 " cold into ice, which is a hard, pellucid,
 " brittle, fusible stone: and this stone re-
 " turns into water by heat; and vapour re-
 " turns into water by cold. Earth by heat
 " becomes fire, and by cold returns into
 " earth. Dense bodies, by fermentation,
 " rarify into several sorts of air; and this
 " air, by fermentation, and sometimes
 " without it, returns into dense bodies."
 See *Newton. Optic.* p. 349, 350.

this

this convention of essential accidents being taken together for the specific difference that constitutes the body, and discriminates it from all other sorts, is by one name, because consider'd as one collective thing, called its form; which, consequently, is but a certain character, or a peculiar state of matter, or an essential modification. Lastly, we would show, that a body being capable of many other qualities, besides those, whose convention is necessary to make up its form; the acquisition or loss of any such quality is termed alteration; as when oil comes to be frozen, change colour, or grow rancid; but that if all, or any of the qualities, reputed essential to such a body, come to be lost or destroy'd, such a remarkable change is called corruption; as when oil takes fire, the oil is not said to be altered, but corrupted or destroy'd, and fire generated; and that when the body is slowly corrupted, and thereby also acquires qualities offensive to our senses, especially the smell and taste, that kind of corruption is called putrefaction: but that nothing substantial, either in this, or any other kind of corruption, is destroy'd, only that particular connexion of the parts, or manner of their co-existence, upon account whereof the matter was term'd a stone, or a metal, or belong'd to any other determinate species of bodies.

S E C T. II.

THE origin of forms, tho' thought the noblest, hath yet been found one of the most perplexed inquiries in philosophy, especially as managed by the schools. The sum of the controversy betwixt us and them, is, whether the forms of natural things be, in generation, educed, as they speak, out of the power of the matter; and, whether these forms are true substantial entities, distinct from the other substantial principle of natural bodies, that is, matter. The reasons which move me to embrace the negative, are principally these. First, I see no necessity for admitting any such substantial forms in natural things; matter, and its accidents, being sufficient to explain as much of the phenomena of nature, as we are likely to understand*. In the next place, I see no use of this puzzling doctrine of substantial forms in natural philosophy; nor can I imagine how particular phenomena should be explain'd by a principle, whose nature is unknown. And, lastly, I cannot conceive, how forms should be generated, as the peripatetics would have it; nor how the things they ascribe to them, are consistent with the principles of true philosophy, or even with what themselves otherwise teach. I know the schoolmen here take refuge in an obscure distinction, and tell us, that the power of matter, with regard to forms, is partly educive, as the agent can make the form out of it, and partly receptive, whereby it can receive the form so made: but, since those who say this, will not allow, that the form of a generated body was actually pre-existent in its matter, or any where else, it is hard to conceive how a substance can be educed out of another

The vulgar doctrine of forms consider'd.

* 'Tis Sir Isaac Newton's first rule in philosophy, that no other causes should therein be admitted, but such as are true, and sufficient to solve the phenomena. *Newton Princip. p. 357.*

PHYSICS.

substance totally distinct in nature from it, without being, before such education, actually existent in it. And as for the receptive power of the matter, that but fitting it to receive or lodge a form, when united with it; how can it be intelligibly made appear to contribute to the production of a new substance, of a quite different nature from that matter, tho' it harbours it when produced? It is plain, that the human body hath a receptive power with regard to the human soul, which yet themselves confess, both to be a substantial form, and not to be educed out of the power of matter. Indeed, if they would admit the form of a natural body to be but a more fine and subtile part of the matter, (as spirit of wine is of wine, which, upon the recess thereof, remains no longer wine, but phlegm, or vinegar,) then the educative power of matter might signify something: and so it might, if they would allow the form to be but a modification of the matter; for then it would import, that the matter may be so ordered or disposed by fit agents, as to constitute a body of a particular sort, and denomination: as the form of a sphere may be said to lurk potentially in a piece of brass, because the brass may, by casting, turning, or otherwise, be so figur'd, as to become a sphere. But this they will not admit, lest they should make forms to be but accidents; tho' it is, for ought I know, as little intelligible, how, what is educed out of any matter, without being either pre-existent, or any part of the matter, can be a true substance; as how that roundness which makes a piece of brass become a sphere, can be a new substance in it. Nor can they admit the other way of educating a form out of matter, as spirit out of wine, because then matter will be corruptible, contrary to their doctrine; and matter and form not be two different and substantial principles, only one and the same, tho' diversify'd by firmness, grossness, &c. which are but accidental differences. I know they speak much of the efficacy of the agent upon the matter, in the generation of natural bodies, and tell us strange things of his manner of working. But not to spend time in examining those obscure niceties; I answer, in short, that since the agent, let him be what he will, is but a physical and finite agent; and since what way soever he works, he can do nothing repugnant to the nature of things; the difficulty with me will still remain. For if the form produced in generation be, as they would have it, a substance, not before to be found, out of that portion of matter, wherewith it constitutes the generated body; either it must be produced by refining, or subtilizing some parts of the matter into form; or else, it must be produced out of nothing; that is, created. If they allow the first, then will the form be indeed a substance, but not, as they hold it, distinct from matter; since matter, however subtilized, is matter still; as the finest spirit of wine is as truly a body, as the wine itself that yielded it; or as is the grosser phlegm from which it was extracted. Besides, the *Peripatetics* teach, that the form is not made of any part of the matter: nor, indeed, is it conceivable, how a physical agent can turn a material into an immaterial substance; especially, matter being, as they themselves confess, as well incorruptible, as ingenerable. But if they will not allow, as they do not, that the substantial form is made of any thing material, they must let

let me believe it produced out of nothing, till they shew how a substance can be otherwise produced, that existed no where before. And, at this rate, every natural body, of a special denomination, as gold, marble, nitre, &c. must not be produced barely by generation, but partly by generation, and partly by creation. And, since it is confess'd on all sides, that no natural agent can produce the least atom of matter, 'tis strange they should, in generation, allow every physical agent the power of producing a form, which, according to them, is not only a substance, but a far more noble one than matter, and, thereby, attribute to the meanest creatures that power of creating substances, which the ancient naturalists thought too great to be ascribed to God himself; and, therefore, some schoolmen have derived forms immediately from God: but this is not only to desert *Aristotle*, and the *Peripatetic* philosophy, which they would seem to maintain, but to put omnipotence upon working many thousand miracles every hour, to perform that, in a supernatural way, which seems the most familiar effect of nature in her ordinary course.

And, as the production of forms out of the power of matter, is, for these reasons, incomprehensible to me; so those things which the *Peripatetics* ascribe to their substantial forms, are some of them such, as I cannot reconcile to my reason: for they tell us positively, that these forms are substances, yet at the same time teach, that they depend upon matter both *in fieri* and *esse*, as they phrase it; so that they cannot so much as exist out of the matter which supports them; which is to make them substances in name, and accidents in reality: for, how can one substance be said to depend upon another *in fieri*, that is not made of any part of it? The very notion of a substance, is, to be a self-subsisting entity, or that which needs no other created being to support it, or to make it exist. Besides, as there are but two sorts of substances, material and immaterial, a substantial form must appertain to one of them; tho' they ascribe such things to it, as make it very unfit to be referred to either. To all this I add, that these imaginary material forms almost as much disturb the doctrine of corruption, as that of generation: for if a form be a true substance, really distinct from matter, it must, as we said, be able to exist of itself, without any other substance to support it: as, those I reason with confess, that the soul of man survives the body, it, before death, inform'd: whereas, they will have it, that in corruption the form is quite abolished, and utterly perishes, as not being capable of existing, separated from the matter, whereto it was united. So that here again, what they call a substance, they make an accident; and besides, contradict their own vulgar doctrine, that natural things are, upon their corruption, resolved into the first matter; since, at this rate, they should say, that such things are but partly resolved into the first matter, and partly, either into nothing, or into forms; which being as well immaterial as the souls of men, must, for ought appears, be also, like them, accounted immortal.

I should now proceed to examine the arguments employ'd by the schools, to prove their substantial forms; but because they are rather metaphysical,

PHYSICS.

or logical, than grounded upon the principles and phenomena of nature, and respect rather words than things, I shall, very briefly, answer only two or three of the most plausible. First, then, they thus argue. *Omne compositum substantiale* (it is hard to english such uncouth terms) *requirit materiam & formam substantialem, ex quibus componatur: omne corpus naturale est compositum substantiale. Ergo, &c.* Now, for brevity sake, I shall here only deny the minor, and desire the proposers to prove it. For I know no thing in nature, that is composed of matter, and a substance distinct from matter, except man, who alone is made up of an immaterial form, and a human body. If it be urged, that then other bodies cannot be properly called *composita substantia*, I shall, rather than wrangle, give them leave to find out some other name for other natural things. But then they argue, in the next place, that, if there were no substantial forms, all bodies would be but *entia per accidens*, which is absurd. To this I answer, that in the notion many learned men have of an *ens per accidens*, as being that which consists of those things *quæ non ordinantur ad unum*, tho' we do not admit substantial forms, yet we need not admit natural bodies to be *entia per accidens*; because in them the several things that concur to constitute the body, as matter, shape, situation, and motion, *ordinantur per se, & intrinsicè*, to constitute one natural body. But if this answer be not satisfactory, I add, that I am solicitous about what nature hath made things in themselves, not what a logician or metaphysician will call them, in the terms of his art; it being much fitter, in my judgment, to alter words to the nature of things, than to affix a wrong nature to things, to accommodate them to a form of words, probably devised when the things themselves were unknown, or not well understood, if thought on. Wherefore, I shall further only consider this argument, "if there were no substantial forms, there could be no substantial definitions; but the consequent is absurd, so, therefore, is the antecedent." I reply, that since the *Peripatetics* confess the forms of bodies to be of themselves unknown, this argument only concludes, that if we do not admit some things, that are not in nature, we cannot build our definitions upon them; nor, indeed, could we, if we should admit substantial forms, give substantial definitions of natural things, unless we could, also, define natural bodies by things that we know not; for such the substantial forms are confess'd to be by the wisest *Peripatetics*, who pretend not to give the substantial definition of any natural composition, except man. But it may suffice us to have, instead of substantial definitions, essential ones of things; I mean, such as are taken from their essential differences, which constitute them a particular sort of natural bodies, and distinguish them from all those of any other kind.

But for fear arguments of this sort should not prevail, some modern assertors of forms have thought fit to add physical ones; which may be more to our purpose here to consider. First then, among the physical arguments, brought to prove substantial forms, the principal is taken from the spontaneous return of heated water to coldness; which effect, say they, must necessarily be ascribed to the action of the substantial form, whose office it is

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to preserve the body in its natural state, and, as there is occasion, to reduce it thereto : which, indeed, might seem plausible, if we were sure that heated water would grow cold again, without the loss of any parts more agitated than the rest, supposing it to be removed into some of the imaginary spaces beyond the world ; but as the case is, I see no necessity of flying to a substantial form : for the water we heat, is surrounded with our air, some vessel, or other body contiguous to the air ; and both the air and water in our climate, are most commonly less agitated, than the animal juices in our hands, or other organs of touch ; which makes us call those fluids cold. Now, when the water is exposed to the fire, it is thereby put into a new agitation, more vehement than that of the parts of our organs ; but when the liquor is removed from the fire, this acquired agitation must be gradually lost, either by the avolation of such fiery corpuscles, as the *Epicureans* imagine to get into heated water, or by its communicating the agitation of its parts to the contiguous air, or to the containing vessel, till it have lost its additional motion, or by the entrance of those frigorific atoms, wherewith (if any such be granted) the air in these climates abounds, and so be reduced to its former temperature : which may as well happen without a substantial form, as, if a ship sailing slowly down a river, should, by a sudden gust of wind, blowing with the stream, be driven on much faster than before ; for the vessel, upon the wind's ceasing, would, without any such internal principle, soon return to its former slowness of motion. So that in this phenomenon, we need not have recourse to an internal principle ; the temperature of the external air, being sufficient to solve it. And, if water be kept in the upper part of a house, where the climate is hot, it will, in spite of the form, continue far less cold, all the summer long, than, according to the *Peripatetics*, its nature requires. And, by the doctrine of forms, the fluidity of water must proceed as much from its form, as the coldness ; and yet this so far depends upon the temperature of the air, that in *Nova Zembla*, vast quantities of water are kept in solid ice, all the year long, notwithstanding the power of a substantial form to preserve it fluid ; which it will never be made, unless by such a temperature of the air, as would itself, for ought appears, make it flow again, tho' there were no substantial form in nature.

Another argument is, that matter being indifferent to one sort of accidents as well as another, it is necessary there should be a substantial form, to keep those accidents, which are said to constitute it, united with the matter they belong to, and preserve both them and the body in their natural state ; for, since it is confess'd, that matter hath no appetite to these accidents more than to any others, they demand how, without a substantial form, these accidents can be contained and preserved ? To this, it might be sufficient to object, that the common notions of the natural and preternatural state of bodies, are false or ill grounded : but to come close to the argument, I answer, that the accidents spoken of, are introduced into the matter by the agents or efficient causes, whatever they be, producing in it, what we call an essential form. And these accidents, being once thus in-

PHYSICS. introduced into the matter, we need not seek for a new substantial principle to preserve them there; since, by the general law, or common course of nature, the matter qualify'd by them, must continue in the state wherein such accidents have put it, till by some agent or other, it be forced out of it, and so divested of those accidents: thus in a brass sphere, when once the motion of tools, impell'd and guided by the artificer, hath turned a piece of that metal to a globe, there needs no new substance to preserve that round figure; since the brass must retain it, till it be destroy'd by the artificer himself, or some other agent, able to overcome the resistance of the matter to be put into another figure. And as, when there is no competent destructive cause, the accidents of a body will, by the law of nature, remain such as they were; so if there be, it cannot be pretended, that the substantial form is able to preserve all those accidents of a body that are said to flow from it, and to be, as it were, under its care and tuition. If, for instance, you expose a sphere, or bullet of lead, to a strong fire, it will quickly lose its coldness, consistence, malleableness, colour, flexibility, and some other qualities; and all this, in spite of any imaginary substantial form. And tho' upon taking lead from the fire, it is reduced to most of its former qualities, yet, that may well be ascribed to its peculiar texture, and the coldness of the ambient air, according to what was said of water, heated and cooled; which temperature of the air is an external thing to the lead: and, indeed, it is but accidental, that the lead, upon refrigeration, regains its former qualities; for, by being exposed long enough to an intense fire, it will be turned into glass, and lose its colour, opacity, malleableness, and flexibility, and acquire a reddishness, a degree of transparency, a brittleness, and some other qualities, that it had not before. And let the supposed substantial form do what it can, even when the vessel is removed from the fire, to reduce or restore the body to its natural state and accidents; yet the former qualities will continue lost, as long as these preternatural ones, introduced by the fire, continue in the matter; and, neither the one will be restored, nor the other destroy'd, till some sufficiently powerful external agent effect the change.

It is, likewise, urged, that no reason can be assign'd, why whiteness should be separable from a wall, and not from snow, or milk; unless we have recourse to substantial forms. But in case men have agreed to call a thing by such a name, because it hath such a particular quality that distinguishes it from others, we need go no farther to find a reason, why one quality is essential to one thing, and not to another. Thus in a brass sphere, the figure is that for which we give it the name: and, therefore, tho' you may alter the figure of the matter, yet by that very alteration, the body perishes in the capacity of a sphere; tho' its coldness may be exchanged for heat, without making it the less a sphere, because it is not for any such quality, but for roundness, that a body is called a sphere. And so firmness is an inseparable quality of ice, tho' a particular figure be not; because it is for want of fluidity, that we call any thing ice, which was immediately before a liquor: and, accordingly, tho' whiteness were inseparable from snow.

snow and milk, yet, this would not necessarily infer, that there must be a substantial form to make it so ; for the firmness of the corpuscles that compose snow, is as inseparable from it, as the whiteness ; and yet it is not pretended to be the effect of the substantial form of the water, but of the excess of the coldness of the air, which puts the water out of its natural state of fluidity, and into a preternatural one of firmness and brittleness. And the reason why snow seldom loses its whiteness, but with its nature, seems to be, that its component particles are so disposed, that the same heat of the ambient air, which is fit to turn it into a transparent body, is also fit to make it fluid ; which, when it is become, we no longer call it snow, but water : so that the water loses its whiteness, tho' the snow do not. But if there be a cause proper to make a convenient alteration of texture in the snow, without melting or resolving it into water, it may then exchange its whiteness for yellowness, without losing its right to be called snow ; as an eminent writer relates, that in the northern regions, towards the pole, those parcels of snow, that have lain very long on the ground, degenerate, in time, into a yellowish colour, very different from that pure whiteness to be observed in the neighbouring snow lately fallen.

But there yet remains an argument for substantial forms, taken from a supposed necessity there is of thence deriving all the various changes to which bodies are subject, the different effects they produce, the preservation and restitution of the state requisite to each particular body, and the keeping of its several parts united into one whole. In answer to this, we might say, that many great alterations may happen to bodies, which seem manifestly to proceed from their peculiar texture, and the action of outward agents upon them, and of which it cannot be shewn, that they would happen otherwise, tho' there were no substantial forms in being : as we see that tallow, melted by the fire, loses its coldness, its firmness, and its whiteness, and acquires heat, fluidity, and some transparency ; but being suffered to cool, it presently exchanges these for the former qualities ; yet several of those changes are plainly the effects of the fire, and the ambient air, not of any substantial form : and it is evident, that fire effects a great variety of changes in qualities, and produces new ones, by its heat, that is, by a modified local motion. I consider farther, that various operations of a body may be derived from the peculiar texture of the whole, and the mechanical properties of the particular corpuscles, or other parts that compose it. And to the pretence, that a substantial form is requisite to keep the parts of a body united, without which it would not be one entire body ; I answer, that the contrivance of parts conveniently figured, and, in some cases, their juxtaposition may, without the assistance of a substantial form, be sufficient. A pear grafted upon a thorn, or a plumb inoculated upon an apricock ; will bear good fruit, and grow up with the stock, as if they both made but one tree, and were animated by the same common form ; tho' both the stock, and the inoculated plant, have each its own form, as may appear by the different leaves, fruits, and seeds they bear. And even vegetation, and the distribution of aliments, are, in such cases,
well

PHYSICS.

well made, tho' the nourished parts of the total plant, have not one common soul or form; which is yet more remarkable in mistletoe, growing upon old hazle-trees, crab-trees, &c. in which the mistletoe often differs very widely from that kind of plant on which it thrives and prospers. And for the durableness of the union betwixt bodies, that a substantial form is not requisite to procure it, I have been induced to think by considering, that silver and gold, being barely mixed by fusion, will have their minute parts more closely united, than those of any plant or animal we know of. And there is scarce any natural body, wherein the form makes so strict, durable, and indissoluble an union of the parts it consists of, as that, which in the factitious concrete, we call glass, arises from the bare commixture of the corpuscles of sand, with those saline ones, wherewith they are melted by the violence of the fire: and the like may be said of the union of the proper accidents of glass with the matter of it, and betwixt one another.

It is still farther alledg'd in behalf of substantial forms, that these being in natural bodies, the true principles of their properties, and consequently of their operations, that natural philosophy must needs be very imperfect, which rejects them. But, if there were, in every natural body, such a thing as a substantial form, from which all its properties and qualities immediately flow; since we see, that the actions of bodies upon one another, are immediately performed by their qualities or accidents; it would scarce be possible to solve many of the explicable phenomena of nature, without having recourse to them: and it would be strange, if many of the abstruser phenomena were not explicable by them only. Yet, indeed, almost all the rational accounts to be met with of difficult phenomena, are given by such, as either do not acknowledge, or, at least, do not take notice of substantial forms. And, it is evident, by the clear solutions of many phenomena in statics, and other parts of mechanics, and especially in hydrostatics, and pneumatics, that they may be satisfactorily solved without employing a substantial form. On the other side, I do not remember, that either Aristotle himself, or any of his followers, have given an intelligible solution of any one phenomenon of nature, by the help of substantial forms: and as their nature is unknown to us, to explain any effect by them, must be to declare *ignotum per ignotius*, or, at least, *per aque ignotum*. For to say, that such an effect proceeds not from a particular quality of the agent, but from its substantial form, is to take an easy way to solve all difficulties in general, without rightly resolving any one in particular; and would make a rare philosophy, if it were as satisfactory as it is easy. If it be demanded, why jet attracts straws, rhubarb purges choler, snow dazles the eyes rather than grass, &c. to answer, that these, and the like effects, are performed by the substantial forms of the respective bodies, is, at best, but to say, what is the agent, not how the effect is wrought; and seems to be such a kind of general answer, as leaves the enquirer as much at a loss for the causes and manner of particulars, as men commonly are for the particular causes of the several strange things performed by witchcraft, when told, that some devil does them.

In short, the form of a natural body, being, according to us, but an essential modification, and, as it were, the stamp of its matter, or such a convention of the magnitude, shape, motion or rest, situation, and con- texture, of the small parts that compose it, as is necessary to constitute, and denominate it a particular body ; and all these accidents being producible in matter by local motion ; we may well say, that the first and universal, tho' not immediate cause of forms, is no other than God, who put matter into motion, established its laws among bodies, and also, guided it in several cases, at the beginning of things ; and, that among second causes, the grand efficient of forms, is local motion ; which, by variously dividing, sequestering, transposing, and connecting the parts of matter, produces in them those accidents and qualities, upon account whereof, the portion of matter they diversify, belongs to a determinate species of natural bodies : yet this is not so to be understood, as if motion were only an efficient cause in the generation of bodies ; for 'tis also frequently one of the chief accidents, as in water, fire, &c. that concur to make up the form*.

S E C T. III.

SOME late writers, as particularly Sennertus, teach that, besides the specific form in plants and animals, there reside, and especially in some determinate parts of them, certain other forms, proper to those parts, but so subjected to the predominant form, as to deserve the title of subordinate; being, during the reign of the specific form, subservient to it ; tho' when the specific form comes to be abolished, these subordinate forms may set up

The doctrine of subordinate forms examin'd.

*This doctrine cannot be better illustrated, confirm'd, and improv'd, than by the words of that incomparable philosopher Sir Isaac Newton. "The vis inertia," says he, "is a passive principle, by which bodies persist in their motion, or rest ; receive motion in proportion to the force impressing it, and resist as much as they are resisted. By this principle alone, there never could have been any motion in the world. Some other principle was necessary for putting bodies into motion : for, from the various composition of two motions, 'tis very certain that there is not always the same quantity of motion in the world." "But by reason of the tenacity of fluids, the attrition of their parts, and the weakness of elasticity in solids, motion is much more apt to be lost than got, and is always upon the decay." "There is therefore a necessity of conserving and recruiting it by active principles, such as are the cause of gravity, by which the planets and

comets keep their motions in their orbs, and bodies acquire great motion in falling ; and the cause of fermentation, by which the heart and blood of animals are kept in perpetual motion and heat ; the inward parts of the earth are constantly warm'd, and, in some places, grow very hot ; bodies burn and shine ; mountains take fire ; the caverns of the earth are blown up ; and the sun continues violently hot and lucid, and warms all things by its light. For we meet with very little motion in the world besides what is owing to these active principles. And, if it were not for these principles, the bodies of the earth, planets, comets, sun, and all things in them, would grow cold, and freeze, and become inactive masses ; and all putrefaction, generation, vegetation, and life, would cease ; and the planets and comets would not remain in their orbs." Newton. Optic. p. 372—375.

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PHYSICS. for themselves; and, in reference to those parts of matter they belong to, exercise the functions of specific forms: as in a dog or a horse, besides the sensitive soul, which is the specific form of the whole creature, the flesh, blood, and bones have their distinct forms appertaining to them, tho' they are ruled and employed by the soul, but as the matter which she animates and informs: and, when by death, the sensitive soul or specific form is deposed or abolished, the body is not presently resolved into the four elements, but those subordinate forms still preserve the flesh in the state of flesh, and the bone in the state of bone; the one for a little, and the other for a much longer time. And this doctrine is urged from the specific virtues observable in gathered plants; as the purgative faculty of rhubarb, senna, and other cathartic vegetables, when they are deprived of the life they enjoy'd as plants. But it were not difficult to propose experiments, which would determine this matter otherwise, were it important enough to deserve it. However, this doctrine of subordinate forms affords such countenance to that of substantial ones, that the nature of our present discourse forbids us to leave it untouched; tho' I shall not pretend to give a full and satisfactory account of so perplexed and abstruse a matter; it may be sufficient, if I at present shew, that subordinate forms are explicable upon other principles.

And, 1. The name form, is a technical word, and not so well defined as were to be wished. But without injury to the more usual notion of it, we may observe that it is commonly some one, or a few considerable things, or conspicuous phenomenon exhibited, or some peculiar operation performed by it, or some particular use, to which it is applicable, upon account whereof a form is attributed to a particular natural body; and only upon the recess or abolition hereof, it is said to lose its form, or denomination. 2. The bodies, supposed endowed with subordinate forms, are, generally, either of the vegetable or animal kind; and, consequently, being of a very compound nature, consist of parts not all of the same species: this is evident in bones, which tho' entitled similar parts, by distillation afford salt, oil, phlegm, spirit, and ashes. And vitriol, tho' similar as to sense, may be artificially produced, by uniting the metalline particles of iron or copper, with the saline corpuscles of distill'd salt or nitre. This instance I chuse the rather, because the patrons of subordinate forms seem, by them, to account for what happens in vegetables and animals, when the ultimate form is abolished or expelled: tho' I see not, why we may not also attribute subordinate forms to several inanimate bodies. To illustrate this matter, let us borrow an example from rhubarb, the purgative faculty whereof is affirmed to proceed from a substantial form; which virtue, whilst the rhubarb grew in the ground, proceeded, as they teach us, from the specific form. Now if from the same rhubarb, we, by a convenient menstruum, extract, together with the finer parts of the body, all the purgative virtue, (which may easily be done) why may not the remaining rhubarb, which will retain several of its former qualities, have a peculiar form, distinct from that which the schools call, *forma mistionis*, to which those qualities may be

be attributed, and which, consequently, may be look'd upon as a subordinate form, with regard to that, which the entire, tho' inanimate rhubarb had before. An olive, or almond, when gathered, ceases to be animated by the vegetative soul of the tree, yet, on account of its subordinate form, retains the same shape, colour, &c. as before, by virtue of which form, it may be preserved sound for a whole year, or, perhaps, much longer: so, by crushing the pulp of the olive, an oil may be squeezed out, endowed with noble qualities, and capable of preserving itself for several years. Now, I see not, why the form of this oil, from whence its qualities flow, may not be looked upon, as having been, whilst the liquor made a part of the olive, a subordinate form to that of the entire fruit. But to make this out by clearer examples; nature, in sulphur vive, has united under one form, two bodies of very different kinds, the one readily inflammable, and the other a great resister of fire; yet these two are easily separable, as appears by burning sulphur under a glass-bell. Again, in fossil cinnabar, under the form of a mineral stone, nature has ranged three, if not more, complete bodies, which have, each of them, its own distinct form, and that exceeding different from the others; as appears when these bodies are skilfully separated: for thence may be obtain'd a running mercury, an inflammable sulphur, and a concrete, whose properties we are not so well acquainted with. Now, if it be said, that these forms are not subordinate, but co-ordinate, it lies upon the objectors to prove it, who, perhaps, will find it no easy matter to shew, that the same ingredient, sulphur, for instance, is not as much subjugated by the form of the entire body, as that of the purgative portion of rhubarb, by the form of that drug. 3. All the different bodies, whereof, as parts, or ingredients, a compound is made up, are, by virtue of the composition and peculiar fabric thereof, so put together, that they concur to those actions or operations, which being proper to the body, are therefore presumed to flow immediately from the form of it. For instance, in gun-powder, three ingredients, upon a very slight mixture, produce, by a concurrent action, those wonderful effects, that are scarce to be match'd in nature; and which really result from the proportion of the ingredients, and the manner of their mixture. 4. Tho' the several parts, whereof the compound consists, do, in the proper actions of that body, jointly concur to perform them, yet these thus conspiring bodies, may, each of them, retain those properties which made it a distinct natural body before it came to be associated with the others, wherewith it makes up a more compound body.

5. And here it may be proper to observe, that the more considerate school-men, teach what very well agrees with the doctrine of subordinate forms. For when, in the generation of man, they tell us, that the *embryo* lives the life of a plant, and of an animal, before he attains to live the life of a man, it is plain, that, upon the introduction of the rational soul, the vegetative and sensitive souls, that before successively inform'd the *embryo*, do so no more; the additional human soul now becoming the true form of the human body. And these pre-existent souls are not abolished, and lose their being, but only their office, which, at first, was to inform the body of the *embryo*,

PHYSICS. and now ceaseth ; so that they are not destroy'd, but only laid aside. And this consideration seems to admit, in many natural bodies, forms, that dispose the matter they modify, for the reception of a nobler stamp, and may, therefore, be call'd preparatory forms, to distinguish them from those more noted forms, which the schools usually term specific ; as in the *embryo*, the vegetative and the sensitive soul, is but preparatory to the rational, which, alone, is said to be the specific form of man. But here I would not be thought to adopt all those opinions, upon which I think it allowable to argue against such as own them. For I take the difference between animating and natural forms to be so wide, that there is no just arguing in physical matters from one to the other. But whether in living creatures, the soul be always the true form, to all the intents and purposes the vulgar philosophers would have it, I shall not here determine ; nor whether, upon the supervention of an ultimate or specific form, the forms, which thereby become subordinate, make but a part of the matter informed by the new one. They may, indeed, qualify the several portions of matter whereto they belong, to be fitter subjects or receptacles for the ultimate form ; and there may be a necessity for such previous dispositions in the subject, because the compound body is of such a nature, that no other bodies, but what are peculiarly qualified, have a fitness to compose it. But it seems hard to conceive, how a substance distinct from matter, can properly be said to have its capacity confounded with that of matter. And, notwithstanding the distinction betwixt specific and preparatory forms, the latter seem as true forms, whilst they are predominant, as the specific themselves. For bodies are what they are, by the matter and modification which, for the present, constitute them, whatever they may afterwards prove : and it is not essential to the form, said to be previous, that it is to be succeeded by another, said to be more noble. A spring of steel, is a true and perfect spring, before it is made a part of a watch ; and, by becoming so, it is not really bettered in its nature, tho' it be thereby made more useful to man.

6. It will not be amiss to make some distinction between subordinate forms ; there being one sort of them, which may deserve a peculiar name. For in men, horses, sheep, and other perfect animals, there are several parts, especially those that physicians call similar, in opposition to organical ones, such as bones, ligaments, membranes, which seem evidently to challenge peculiar and distinct forms : for the diversity of their nature being very manifest, often persevering a great while after death ; those, who allow a natural body to be what it is upon account of its form, cannot well deny distinct forms to these so distinct bodies ; which, because the bodies they constitute, are the parts of a human body, some school-men have called partial forms.

7. Among the constituent parts of an animal or plant, there may lurk some seminal principles, or rudiments, that is, small parcels of matter of such a texture, that, tho' whilst they remain associated with the other parts of the compound body, they are not, by sense, distinguishable from the rest ; yet, when it comes to have its predominant form abolished, these seminal prin-

principles or rudiments being set at liberty, and assisted by external heat, and the softness which usually attends corrupting bodies, and, perhaps, by a lucky concurrence of other circumstances, may fall to act according to their own nature, and generate insects, moss, &c.

8. We may add, that when the specific form of a body is destroy'd, the change is not often so great, as vulgar philosophers imagine. The corruption of an animal, or other body, ought not to be looked upon, as happening in an empty space beyond the universe, but in our system, where being deprived of its specific form, 'tis subject to be acted upon by the sun, the air, and many powerful agents; by whose various concurrence with, and operations upon it, either the late pre-existent forms may be assisted to set up for themselves, or new forms result from new associations and contextures of the particles, which composed the body, now destitute of its principal, or sovereign form.

Thus much being premised, let us try whether the corpuscular philosophy, according to which we have hitherto discoursed of forms, will not solve the phenomena, mention'd by *Sennertus*, better than his hypothesis. I allow him to have rightly asserted, that in a plant or animal, there is something besides the bare *materia prima*, and the vegetative or sensitive soul, with its essential faculties. And that in some parts of such bodies, there may lurk peculiar forms, which, when the life of the plant or animal determines, come to disclose themselves, seems probable, from the instances of the specific virtue, surviving in gather'd plants. It is probable too, what *Sennertus* teaches, that this purging property in rhubarb, senna, &c. as it does not flow from the vital soul of the plant, which is already destroy'd; so it does not proceed barely from the form of a mere mixed body: for it is no way likely, that so great a variety of specific properties, wherewith roots plucked out of the ground, and fruits torn from the tree, are endowed, should proceed merely from that general form, which belongs, in common, to compound bodies, as such. But tho' there are some parts of this doctrine of subordinate forms, wherein I dissent not; yet, there are others, wherewith I must confess myself unsatisfied. We are taught, indeed, that the specific form of a body commands all the subordinate forms; but I do not readily conceive, which way this dominion, attributed to the specific form, is exercised; nor see any necessity of admitting such a power in that form; or that the portions of matter, endowed with those forms, said to be subordinate, can, being under the degrees of souls, and, consequently, unfurnished with knowledge and will, shew this presumed superintendent form any other obedience, than such as the parts of a clock or engine may be said to yield to one another. I should, therefore, rather conceive, that when several bodies of differing natures are associated, to compose a body of one denomination, tho' each of them be supposed to act according to its own peculiar nature; yet, by reason of the coaptation of the parts, and the contrivance of the compound body, it must often happen, that the action, or effect produced, will be of a mixed nature, and different from that, which several of the parts, consider'd as distinct bodies, or agents, tended to, or would have performed.

PHYSICS. formed. Thus, in a balance, by putting a weight into one of the scales, the opposite, tho', as a heavy body, it has a natural tendency downwards, will, by virtue of the fabric of the instrument, mount upwards. So that those actions, which *Sennertus*, and others, attribute to the conspiring of subordinate forms, to assist the specific and presiding form, we take to be but the resulting actions of several bodies, which, associated together, are thereby reduced, in many cases, to act jointly, mutually modifying each others actions; and that which they ascribe to the dominion of the specific form, I attribute to the structure, and especially to the connexion of the parts of the compound body. Thus, in a clock, tho' all the parts whereof it consists, contribute to the performance of the things belonging to a clock, as regularly as if they intended to do so, and did not only concur, but knowingly conspire thereto; yet, in all this there is no substantial form to superintend their motion, but the weight tends downwards, as usual; and the hand, wheels, and other parts, only perform such motions, as they are forcibly put into by those bodies, which, by the descending weight, are themselves set in motion. And, even the prodigious effects of gun-powder, are owing to the mechanical texture, and that slight and easy way, wherein the ingredients are mixed; which are also with ease dissociated, by a chymical process.

But to illustrate resulting actions by an instance purely physical; by taking two powders, fit for my purpose, one blue and the other yellow, and mixing them in a certain proportion, the mixture exhibited a green colour, which did not flow from any new predominant form, making the blue and yellow corpuscles subservient to its purposes; but only, from the mixture of those bodies, the distinct actions of the blue and the yellow corpuscles made upon the eye a compound impression, like that of bodies, whereto their specific forms are supposed to impart, among other qualities, greenness. Thus also, when vitriol, and sublimate, are made by art, there needs nothing, besides the manner, wherein the saline, and metalline particles are contended, either to hold the parts together, and keep them united into one body, or to enable the mixture to effect several things, which neither of them would have performed apart. And, as in a watch, the spring is really a spring, and acts as one, whilst it is a part of the watch, tho' by reason of its connexion with the other parts, it is reduced to concur, with those, towards exhibiting the phenomena proper to the whole engine; so, in many compound bodies, besides the specific form, which the body has, as such, and which may be call'd its total or general form, the particular bodies, (by whose association and conjunction it is made up) may enjoy their own distinct forms, and be therefore called partial forms: and these bodies, tho' they are part of the whole, whilst it subsists, and, by their connexion with the rest, concur to the operations of the body, as such, (which joint operations are usually attributed to the specific form) yet they do not always so depend thereon, but after it is abolished, they may retain their own nature; as a bone, will be a bone for whole ages after the animal it belonged to is dead. Whence we need not wonder, that several forms should survive in

in bodies deprived of their specific form. For, indeed, those which are called subordinate, may, as was before observed, be as true and real forms, as those which bear the title of specific; and even, whilst these are in being, there are many things which compound bodies perform by virtue of their particular forms, rather than of the specific. Thus in gun-powder, the blackness proceeds not from the composition, but the coals; and the nitrous taste from the salt-petre.

If we consider the arbitrary use of the word form, we shall find, that those things, upon account whereof we attribute a particular form to a natural body, are but very few of the many attributes which belong to it. Now the form of a body being really no more than a convention of attributes, whereby the matter is stamped, and denominated; it is very probable, that hostile causes may often deprive the matter of those accidents, which constituted the specific form, and yet leave the rest, which, according to the law of nature, ought to continue there, till some competent agent put the body out of that state, wherein, upon the form's decease, it was left. To clear up this matter, we must consider, that the same body may have two kinds of modification, and be thereby fitted for two, if not more, states and kinds of operations, not necessarily dependent upon each other. For, as the spring of a watch is, by virtue of one part of its texture, an elastic body, and, upon account of another, iron; and, therefore, tho' being cast red-hot into cold water, it will become stiff and brittle, and, consequently, cease to be a spring; yet it will still continue iron, with all its peculiar attributes. Thus in a rose, we may distinguish two modifications of the matter; one, whereby it is fitted to receive, from the bush it grows on, a certain peculiar and spirituous sap, by whose intervention and concurrence, it has nourishment and growth, and, consequently, exercises vital functions, as a part of a living plant; and another, which consists rather in the texture of the more stable parts: and this texture being commonly more permanent and durable, than the other part of the modification, wherein the life, participated by the rose, consisted, may last, when the flower is deprived of its soul and specific form, by removal from the bush, and retain those qualities, that naturally result from a parcel of matter so contrived. And, as a mill is capable of performing several things, only when the water, that passes through certain parts of it, puts them, and, by their means, others, into motion; so there are many things not performable by a plant, unless watered with a vital liquor. And, as a mill may, nevertheless, retain the nature of a structure, useful for other purposes, tho' the drought of summer have, perchance, depriv'd it of its water, or the frost congeal'd it into ice; so, tho' the soul of a plant be destroy'd, or cease to act, the body may, upon account of the more permanent structure of its stable parts, retain a fitness for many of the same purposes whereto it served before. This comparison, perhaps, will not hold in all circumstances: however, there are several instances of vegetables resuming the faculty of growing, long after they have been thought lifeless; as the rose of *Jericho*, the aloes-plant, &c. And even some animals are not so very unlike these plants, as one would imagine: for flies, wasps, &c. will

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PHYSICS.

perform their usual actions, upon the application of fresh warmth, some time after they have seem'd to be dead.

To proceed, it may be observed, that even in a body, which hath lost its specific form, the remaining qualities do not always flow from the form of the entire body ; but from the peculiar form of some particular parts of it, which being separated therefrom, tho', perhaps the more stable parts that remain, will keep the visible structure from being manifestly altered ; yet this remaining body shall be quite deprived of its noble properties ; as may appear from making the extract of rhubarb, wherein its whole purgative virtue resides ; and from some preparations of cinnamon, and other substances of fine parts, which, upon the loss of them, remain but the carcases of what they were. And, besides this pre-existent and surviving modification, it is often very possible, that new qualities and properties may be disclosed upon the abolition of the specific form, tho' they were not actually in any part of the matter, but are produced in it by a concurrence of the texture and dispositions left there by the late form, and the operation of external agents. As, when out of the flesh of a dead animal, musk or insects are generated ; or, as when a lime-stone calcined, and left in the open air, in time affords true and inflammable salt-petre. But as to the two modifications of living creatures before-mention'd, I fear we sometimes attribute to the specific form, things, that may be well perform'd without it, by the more stable modification of the body, assisted by an easy concurrence of natural agents. Thus, tho' the exclusion of excrements be unanimously ascribed to the soul, which, for that purpose, is said to be endowed with a peculiar faculty, call'd expulsive ; yet, the excrements have been often discharged, long after the creatures were unquestionably dead. And tho' the maturation of fruit be a great alteration, supposed to be wrought by the vegetative soul of the plant ; yet it has been observed, that apples, grapes, &c. gathered before they were ripe, and laid on heaps together, will ripen well enough afterwards : and the common histories abundantly prove the same in other the like productions. I might add, that even in our cold climate, onions, and some other bulbous plants, will, in the spring-time, shoot out of their own accord. And, even in animals, some things, confidently presumed to be the proper effects of the soul, may be really performed by the texture of the body, and the ordinary and regular concurrence of external causes ; as the growth of nails, hair, &c. after death, which continues not only whilst the impressions left by the soul upon the carcass, are yet vivid and recent, but for a much longer time than hath been imagined ; a memorable instance of which is given by *Paraus*, who, speaking of a body, which he, by embalming, preserved for more than twenty five years, affirms, " that it still remained whole and sound ; and as to the nails, having often pared them, he always observed them to grow again to their former length."

The patrons of *Sennertus's* opinion, look upon it as a cogent argument to prove, that the soul performs almost all that is done in the body, because in the corps of a man newly dead, tho' the organization remain the same, yet the animal and vital functions perfectly cease. But tho' the visible fabric may

may continue, for a while, without any manifest alteration; yet, who can assure us, that the internal organization is not considerably changed and vitiated? The body of an animal consists not only of solid and stable parts, as bones, muscles, &c. but of several soft ones, as the brain, nerves, &c. and of some that are fluid, as the blood, and other juices; and, which is, in our case, very considerable, requires a convenient combination of all these: whence it follows, that the external frame of the body remaining unaltered, yet, upon death, there may be great alterations in the texture of the blood and humours, and in the structure of other internal parts. And these changes may quite spoil the organization of the body, and render it unfit to perform the usual functions of such an engine. But some of the things hitherto delivered, may be disputed for want of ascertaining the meaning of the word, life; which is indifferently apply'd to minerals, plants, animals, and spirits: and it is very difficult to avoid mistakes, or unprofitable disputes, if men do not use words in the same signification. It may, therefore, be convenient to dismiss so much of the controversy, as, on this account, is liable to ambiguity, and apply the chief points of our doctrine of subordinate forms to inanimate bodies. And here, for order's sake, I shall cast the principal things into distinct propositions, and annex a short comment to each.

1. *The word form has a very indeterminate signification.* This we have already shewn; and the persons, who use it, do not yet pretend to have agreed, how many, or what things, are sufficient to entitle a portion of matter to a determinate and distinct form. For there are many bodies, such as treacle, beer, gun-powder, coal, ink, &c. about which, men seem not to have consider'd, whether they ought to have particular forms assign'd them; and there are others, about which the *Peripatetics* dispute, whether they should have particular forms allow'd, or no. Ice is, by some, made to be a distinct kind of body, whilst others will have it to be only water altered, and thereby deprived of its fluidity, not its form. Nay, even about the elements themselves, the school-men fiercely dispute; a whole party denying them to have any other forms, than the first qualities, by which they are usually distinguished. And, some bodies, variously consider'd, seem to have a title to more than one form: for instance, it is difficult to determine, whether pure lead, made into a body, like *Vitrum saturni*, is most properly a metal, or glass. The like difficulty occurs, when mistletoe grows very large on a hazle, or when an apricock or a peach is inoculated, and prospers upon the bough of a plumb-tree; and when red or blue amel is made of calcined tin, which they call putty, and of the salt and sand, whereof the glass-men make what they call their fritta, and of some burnt copper, or other metalline pigment; examples, with others of the like kind, which might, perhaps, somewhat perplex the school-men to accommodate fairly to the vulgar doctrine of forms, at the introduction whereof, probably such instances were never thought of.

2. *It is difficult to decide the nobleness of forms.* This point, also, has been partly handled already; and, indeed, as nobleness is rather a civil or political, than a physical qualification, it is often hard to determine, which, of

PHYSICS. two forms, is the most noble. To some examples already given of this difficulty, besides the late instance in glass of lead, may be added that of antimony made *per se*; crude antimony being fitter for several purposes, both mechanical and medical, than the vitrified calx; and this, again, being fitter for other uses, than that, which has not been freed from its more fugitive parts. It was a dispute among the antients, whether their *Electrum*, a composition of gold and silver, was nobler than either of those metals; and when chymists have made a precipitate of gold and mercury, it is questionable, whether that be a nobler thing, than the gold alone; tho' if a chymical physician were judge, he would give it for the gold improved by the change; tho' a goldsmith would conclude it debased by the alloy, and, by melting it with borax, free it from the quick-silver, and restore it to its pristine form. It might, also, be disputed whether, tho' in living creatures the ultimate form be more noble than its previous harbinger; it may not be sometimes otherwise in bodies inanimate, as well as in the productions of art. When an artificer makes silver folder, by adding to the silver a certain proportion of brass or copper, tho' he thereby obtains an useful mixture, yet it may be much questioned, whether this brittle substance be not less noble, than the silver alone. And when a plant, growing by some petrifying spring, is, by imbibing that water, turned, at length, into a stone, tho' the rarity of such things makes men prize them; yet it may well be questioned, whether the new form be not less noble, than that which the plant had before.

3. In many bodies, the form is attributed upon the account of some one eminent property, which, if it be present, and continue, tho' many other things supervene, or are wanting, the matter is still looked upon as retaining its form, and, therefore, allowed its usual denomination. An example of this, we are furnished with, by the late instance of *vitrum antimonii*; for tho' in many respects, it puts on the appearance of glass, yet it retains so much of the antimonial nature and properties, as to be vomitive and purgative, as well as *crocus metallorum*. The expressed oils of olives, almonds, and other unctuous vegetables, differ much from those fine essential oils, drawn by distillation; and both of them from those empyreumatical ones distilled in retorts by violent fires; yet all these very different liquors are reckoned among oils, because they agree in being fluid bodies, unctuous to the touch, and such as will not mix with water. So, altho' some salts are very fugitive, as those of harts-horn, urine, &c. others very fixed, as that drawn from the calx of tartar, or the ashes of wormwood, &c. yet all these are numbred among salts, because they agree in the respects for which we allow bodies that denomination. And, indeed, by reason of the unsettled notion of the word form, and its uncertain application to constitute distinct classes or kinds of bodies, I have doubted, whether several forms be more than metaphysical conceptions; by virtue of which, bodies, very different in nature, are comprized in the same denomination, because they agree in a fitness for some use, or in some other thing that is common to them all, rather than in such true physical forms, as make bodies of the same denomination, likewise of the same specific nature. However, these forms

forms seem to be very generical things, and more so, than is commonly observed. And I have also questioned, whether some of those things, upon account whereof men rank bodies in a particular species or classis, be so properly the true and intrinsic forms of those bodies, as certain states of matter, wherein bodies, very differing in nature, may agree; as water, wine, and many other different liquors, may, each apart, be made, by congelation, to pass into that sort of body we call ice: and not only the suet and fat of animals, and the expressed oils and spirits of fermented vegetables, but also several mineral, and metalline concretes, may be made to pass into that class of body we call flame.

4. *By reason of the conjunction or connexion of the parts that make up a whole, several things will often be performed by the concurrent action of these united parts.* Such operations are of kin to those, which the schoolmen call *actiones communes*; as when a bullet is let fall upon a pavement, tho' it touches the body it falls upon, but in a very small part of its superficies, yet the plane receives the action of the gravity of the whole body; those parts that do not immediately touch it, striking it by the intervention of those which do. So, likewise, in a boat, the limbs and clothes of a man, who stands upon the deck, and all the parts of a watch, if he carries one in his pocket, jointly gravitate on the vessel, tho' only the soles of his feet, or shoes, immediately press upon it; and the wheels and other parts of the watch may be moving, at the same time, very different ways. Now, in organical bodies, and several others, both natural and factitious, those things which are performed by the parts, as in a state of conjunction, are often ascribed to the form; as in a watch, most of the principal phenomena so depend upon the concurrent action of the several parts, that few of them can be out of order, but they will hinder those phenomena from appearing at all, or, at least, from being well and regularly produced.

5. *We may yet, in a due sense, admit, that in some bodies, there are subordinate forms.* I know it is pretended, that one body can have only one form: but tho' a body can have only one total and adequate form, yet, its parts may have their partial forms subordinate to that; as the steel-spring, and brass-wheels, of a watch, may retain their distinct metalline forms, tho' the watch they compose be but one. And the schoolmen themselves, with many of the antients, have asserted, that in compound bodies, the elements retain their respective forms, notwithstanding the new form, that belongs to the mixed body. It is also objected, against the supervention of a higher form, that a body, being already complete in its own kind, by its own form, noother form can accrue to it, without making what is called *ens per accidens*. To this I answer, that the notion of an *ens per accidens* belongs rather to metaphysics, than natural philosophy; and in what its essence consists, is still so hotly disputed, that no arguments from it, can justly affect the present case: and, indeed, when we consider, that the schools allow the soul and body to make up a man, who, according to them, is *unum per se*, and not *per accidens*; and teach, that the rational soul, which is a substance, and the understanding and will, which are said to be its faculties,

PHYSICS.

culties, and so its accidents, make *unum per se*; by a parity of reason, that predicate or qualification, may well be taken in as large a sense as is requisite for our purpose. So that if the parts of a body, whether natural or factitious, be, by their union, brought to become the principle of a property or operation, which belongs to neither of them single, I see not why such a body may not pass for *unum per se*, as well as several bodies which pass under that notion. It may be farther answered, that tho' a body, by its own form, be complete in its kind, yet it may be capable of advancement to a nobler state by an accession, that shall not ruin its former nature, but enable it to co-operate to nobler actions, than its former could reach. Thus when a spring is made part of a watch, it thereby, without losing the nature of a spring, contributes to the noblest phenomena of so curious an engine: and the ingredients of gun-powder, by the superinduction of the form, or new texture they acquire by mixture, are, each of them, enabled to co-operate to the performance of things, far exceeding the utmost they could do before. Nor will it follow from this superinduction of forms, that there may be a form of a form, as well as of matter; but only that to a body, which hath already a form, a farther form may supervene.

6. *The supervention of a new form is often but accidental to the pre-existent form; and does not at all destroy its nature, but modify its operations.* A needle, not touched by a load-stone, has its own form, as a piece of steel, as well as the figure of a needle; but, when it comes to be excited by the load-stone, there are then new and wonderful properties superinduced; and this needle is then able to point regularly north and south, attract other needles, and communicate a verticity to them; and so is fit for much nobler uses, than before. And this new modification so regulates its motions, that, tho' before it was indifferent, if nicely poised, to rest at any point of the compass; it is now determined to keep moving, till it points north and south, and to rest in that position only: yet, by drawing this magnetic needle, after a certain manner, upon the pole of a vigorous load-stone, you may, in a moment, deprive it of all its additional faculties, tho' it will remain as true a steel-needle as at first. And a little reflection on the fore-mentioned instance of the spring of a watch, will shew what it is, that the structure or modification, whence the form of the whole, according to us, results, does to a body already endowed with its own form. For, as the spring, tho' it retain its own nature, and acts according to it; yet, by the contrivance of the watch, it is not only so pent in, that it cannot gain its full extent, as otherwise it would, but by the same contrivance, its incessant endeavour, to stretch itself, is so moderated and managed by the wheels and balance, that it principally concurs to set all the other parts in motion, and to perform the office of a watch: so in natural bodies, what is performed by the supervention of a higher and total form, is, that by virtue of the connexion and structure of the parts introduced with this new form, the action of the particular parts, tho' they retain their own partial forms, and act, as far as they can, according to them, is so mastered, or otherwise modified, that they are brought to concur to those things that are done by
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the whole body as one agent, and become subservient to the operations, that are proper to the body in its new and ultimate capacity. Thus when a piece of lead is, without addition, vitrified by the mere action of the fire; this happens to the body, upon its acquiring the form of glass, that, whereas, before, the metalline particles were so inconveniently situated, and shaped, that they denied passage to the rays of light; and, by reason of their contexture, composed a body that was very flexible; they become now so ranged, and otherwise altered, that they freely suffer the light to pass them, but admit not of being freely bent as before. And when salt-petre, by the addition of a small proportion of brimstone and coal, is made into gunpowder; this happens to it, from its acquired modification, that if a little fire fall thereon, it will not, as before, leisurely consume, and leave behind it a considerable portion of the whole body, in the form of a fixed or alkalizate salt, but fly away all at once, and leave little or nothing behind it.

7. Besides the specific actions of a body, that harbours subordinate forms, there may be several others, wherein some of the parts act according to their particular and pristine nature. This follows from what we lately shewed, that the total and specific form has not such a dominion over the partial and subordinate ones, as the patrons of these forms imagine. For tho' by virtue of the modification of the whole, the operations of the parts or ingredients are so guided, as to concur to those operations that belong to the whole, and are requisite to be performed by a joint-action; yet, in other respects, as it is not necessary, that such bodies should have their parts entirely under the dominion of the ultimate form, they may act according to their distinct and particular qualifications. But this will be farther cleared by shewing, that the same things may happen to several bodies, which appear in a watch, where, tho' the form of the engine, in many respects, makes the springs and wheels, and other parts, concur to perform the operations proper to such an engine, yet the wheels may look bright and yellow, the spring may move a magnetic needle, and other parts may do other things, not by virtue of the form of a watch, but by virtue of their own qualities. Thus when in pills, and other medicines, made up of several ingredients, the composition has some resulting virtues distinct from those of the ingredients, and belonging to the composition; yet, it may often happen, that some particular ingredient will not only retain its former nature, but so retain it, that the composition is endowed with that quality, only upon account of that ingredient. Thus ambergreece, mixed with purgative ingredients, retains its own grateful smell, and communicates it to the whole mass, whereof the pills are made: and most purging pills taste strong of the aloes, whatever the other ingredients be. A farther instance we may take from Venice treacle, not too stale: for tho' it be acknowledged, that opium works by a specific quality; and tho' it be here blended with above threescore other ingredients, in far greater quantities; yet, in spite of the *forma compositi*, it retains its proper narcotic virtue; and, upon that account, renders the whole a powerful remedy in several distempers, where quieting medicines are proper. A no less evident example we have in the precipitate of gold and mercury: for tho'

PHYSICS. by virtue of the union of the ingredients, the resulting powder may gain several qualities, which neither the gold, nor the quick-silver, had apart; yet, the salivating faculty of this precipitate, belongs to it barely on account of the mercurial ingredient.

8. *That which, in many bodies, is looked upon as the specific form, is, often, only the most eminent.* We must here recollect, (1.) That the word form, has no settled signification; so that several bodies to which particular forms are assigned, deserve not that privilege better than many others, wherein no peculiar and distinct form is consider'd. (2.) That the forms of inanimate bodies are but respective things, resulting from the co-existence of particular corpuscles or parts, after a determinate manner. (3.) That it is usually from some particular respect, or fitness to some particular use, that men ascribe this or that form to a particular body. (4.) That the nature and fabric of a body may manifestly fit it to answer more than one of those respects, on whose score bodies are denominated, or may be suited to more than one of those uses; an aptitude for which, when found single in another body, is sufficient to make it be referred to a distinct kind: as the *vitrum antimonii*, tho' consider'd by some as glass, is, by a physician, looked upon as a medicine. (5.) That it is not necessary, these conjugations of qualities should have a strict dependence upon one another; as the emetic properties of the antimonial glass belong not to it as glass: nor is it necessary that, if this very portion of matter had not the form of glass, it would want or lose these properties. (6.) That since the nobleness or ignobleness of forms depends on the greater or less use of the body; one man may, in the same body, look upon one kind of modification, and another upon a quite different one, as the highest form of that body. Thus a watch, that shews only the hours and their quarters, hung at a string, and made to swing as a pendulum, would to an astronomer, who was to make nice observations, be most useful in the capacity of a pendulum; because, as that, it may divide a minute into seconds, half seconds, &c. but for other men, who, tho' they want an instrument to measure time, require not such minute subdivisions of it; the little engine we speak of, will be much more useful and considerable, in the capacity of a watch. (7.) Hence it may often happen in inanimate bodies, whether natural, or factitious, that the ultimate or chief form, is not the presiding form, but only the most eminent; by which, I mean not simply the noblest, but that which is, for the time at least, the most considered: or, in other words, the form most regarded, is not so much that which reigns, as that which denominates.

9. *These forms seem to be rather concurrent, than subordinate.* For if a body can have several such conjugations of accidents or modifications, as may entitle it, in differing respects, to different forms; and that form, which is considered as the most eminent, be not the presiding form, nor so much as always the noblest; may not these forms, which co-exist in the same body, be more fitly termed concurrent or coincident, than subordinate? And, indeed, as to inanimate bodies, this dominion and subjection, which is imagined between forms, seems to me, in many cases, neither well established,

blished, nor easy to be explained. I doubt too, that sometimes we mistake names for things; and because, when a body, by the action of proper agents, obtains such a modification as fits it for particular actions and uses, we call it by a certain name, and attribute a form to it; we are apt to conclude, that the faculties and qualifications it enjoys, and the things it is able to do, are owing to this form, as if it were some distinct and operative substance, put into the body; and really began, guided, and over-ruled the motions and actions of the composition. Whereas, indeed, what we call the form, if it be not, sometimes, little more than one of those airy things, which the schools call an external denomination, seems often to be rather a metaphysical conception, than a physical agent, that performs all things in the body it is ascribed to. Thus when a piece of steel, conveniently shaped, is, by a due temper given it, turned into the spring of a watch; the motions of the watch, tho' proceeding from this spring, proceed not from the form of the iron; and the springiness itself, flows not immediately from that form, but from a mechanical and adventitious texture, superinduced in the metal, and given it by several outward agents, as the fire, the hammer, &c. And it is so far from evident, that, in bodies inanimate and compounded, the most eminent, and most considered form, must have a dominion over, and an efficacy in all operations and actions of the composition, that even in bodies not so compounded, it is not always necessary, that the specific form should have so much as a concurrent share in what is performed: for external agents may introduce such qualities into the body we speak of, as, being once there, will suffice for actions and productions, suitable to their own nature, whether the form be active in assisting them or no. We see that boiling water, taken off the fire, will raise blisters on a man's hand, and perform other things, which are usually the effects of fire, only by virtue of the adventitious heat it has received; tho', according to the *Peripatetics*, the form of water, which is an element naturally cold, as well as moist, ought rather to oppose, than promote the action of the preternatural heat. And the like might be said of a heated iron taken from the fire. It may, indeed, be pretended in favour of the schools, that it is the fire, which got into, and yet remains in the iron, that caused these effects. But this subterfuge would involve them in very perplexing difficulties. However, I will put a case where it cannot be made use of: suppose, then, the iron to be heated, not by the fire, but by forcible strokes between a hammer and anvil, both of them actually cold. When a piece of silver is, by being hammer'd, or drawn into wire, made a springy body, it will be able to perform many things by that acquired elasticity, which do not at all flow from the form peculiar to the metal: for not only copper, steel, and many other bodies, may be made springy too; but, if you heat it in the fire, the goldsmith will assure you, that it is as true and as good silver as before; and yet it will cease to be a spring. And so when a smith makes a file, by forming many little channels on it, a-cross one another, and, afterwards, hardening the steel; by virtue of this roughness, which is given it by external agents, it acquires a durable roughness, upon which account it is qualified to perform

many

PHYSICS.

many considerable things, whereto the form of the mere metal does not, for ought that appears, concur. And tho' hardness contributes to make a good file, yet, not only the iron was as true and perfect iron, before it became rough as afterwards ; but even that degree of hardness, which qualifies our instrument to be a good file, flows not immediately from the form of the metal ; for that was true iron when soft, and its eminent degree of hardness was given it by the temper it received from the smith.

But, to conclude, I must again complain, that the uncertain signification and use of the terms, employ'd about these points, are apt to occasion much darkness and difficulty in our enquiries into the things themselves ; and, I am apt to think, that if the meaning of the terms, form, life, soul, animal, vegetative, and some few others, were clearly defined, and agreed on, a great part of the perplexing controversies, about subordinate forms, with what relates to them, would appear to be disputes about words only. And if I should, any where in this discourse, have dropt into a verbal controversy myself, I can safely say, that my endeavours have all along been to expunge received errors, and to establish a better theory of these matters.

S E C T. IV.

*The production,
and re-production,
of forms.*

WE have already seen, it is by a kind of tacit agreement, that men distinguish the species of bodies ; and that those distinctions are more arbitrary, than most are aware of : nor have I yet met with any genuine and sufficient boundary for the species of things, or any determinate number of qualities, necessary to constitute distinct kinds of natural bodies. We, therefore, look upon those as distinct species of bodies, that have had distinct names assign'd them ; tho', perhaps, many of them differ much less from one another, than other bodies, esteem'd but of one sort. Whether water and ice ought to be esteemed distinct bodies, is so little evident, that some affirm, water loses not its own nature, by being turned into ice ; which is made plausible, by the reducibleness of it back again into water : yet others again make them distinct species of bodies, because the one is fluid, and the other solid ; and, also, because ice is, commonly, more or less opaque, and lighter *in specie*, than water. We may add, that ice, beaten with common salt, will freeze other bodies, when water, mixed with salt, will not. And I would be resolv'd, whether must, wine, spirit of wine, vinegar, and tartar, are bodies specifically distinct. The like question might be asked of an egg, and the chick that is afterwards hatched out of it ; as also, of the eggs of silk-worms, which are first small caterpillars, then aurelia's, and next butter-flies. And whether the answer to these queries be affirmative or negative, I doubt, the reason that will be given for either, will not hold in several cases. And it may still be more puzzling to ask, whether a charcoal, thoroughly kindled, differs specifically from another charcoal. Nor is it easy to determine, whether clouds, rain, hail, and snow, be all specifically distinct from water, and from each other.

But

But if such slight differences discriminate these bodies, it will be hard to give a satisfactory reason, why other bodies, that differ in more considerable particulars, should not enjoy the same privilege; as, I presume, that snow differs less from rain, than paper from rags, or glass, made of wood-ashes, from wood. And, indeed, men having, by tacit consent, agreed to look upon paper, glass, soap, sugar, brass, ink, pewter, gun-powder, &c. as distinct sorts of bodies; why may they not be thought to have done it on as good grounds, as those, upon which many other differing species of bodies have been constituted? It will not suffice to object, that these bodies are factitious; for it is the present nature of bodies, which ought to be considered in referring them to species, which way soever they came by that nature: for salt, which, in many countries, is made by boiling sea-water in proper vessels, is as true sea-salt, as that which is made in the isle of *Man*, by the bare action of the sun upon the sea-water, left behind in hollow places, after a high spring-tide. And silk-worms, hatch'd by the heat of a human body, and chickens produced in *Ægypt* by the heat of ovens or dunghills, are as true silk-worms and chickens, as those which are hatched by the sun or by hens.

And whatever may be said of factitious bodies, where man, by instruments, only gives figure to the sensible parts of matter, as when a statuary makes an image; yet the case may differ in those other factitious productions, wherein the insensible parts of matter are altered by natural agents, which perform the greatest part of the work among themselves, tho' the artificer be assistant in putting them together. And, therefore, all chymical productions may well be look'd upon as natural bodies; since the fire, which is here the grand agent, doth not, by being employ'd by the chymist, cease to be a natural agent; since nature herself, by the help of the fire, sometimes affords us the like productions, wherewith the chymist presents us. Thus in *Ætna*, *Vesuvius*, and other burning mountains, stones are turned into lime, and sometimes vitrified, whilst ashes, and metalline-flowers of several kinds, are scattered about the neighbouring places; and plenty of flowers of sulphur, sublimed by the internal fire, appear about the vents, at which the fumes are discharged into the air. And many bodies we meet with in the lower parts of the earth, and think to have been formed there, ever since the beginning of things, may have been more lately produced, by means of subterranean fires. Thus lead may be turned into minium, and tin into putty, or several saline and sulphureous corpuscles, rising in fumes, may alter the nature of other subterranean bodies; or, by convening among themselves, constitute particular concretions; as the fumes of sulphur and mercury unite into vermilion, which is so like to the mineral, whence we usually obtain mercury, that they both go by the same name of cinnabar. Since then these productions, being of nature's own making, cannot be denied to be natural bodies; why should the like productions of the fire be thought unworthy that name, only because the fire, which made the former, was kindled by chance in a hill, and that which produced the latter, light up by a man in a furnace. And if flower
of

PHYSICS. of sulphur, lime, glass, and melted mixtures of metals and minerals, are to be reckoned among natural bodies; it seems but reasonable, that, upon the same grounds, we should admit flowers of antimony, glass, pewter, brass, and many other chymical concretes, to be taken into the number; and then it will be evident, that to distinguish the species of natural bodies, a concurrence of accidents will be sufficient, without considering any substantial form. But because we need not have recourse to instances of a disputable nature, for the illustration of the mechanical production of forms, let us examine only that of vitriol. For, since nature herself, without the help of art, often produces that concrete, there is no reason why vitriol, produced by easy chymical operations, should not be looked upon as a body of the same nature and kind. And in factitious vitriol, our knowing what ingredients we make use of, and how we put them together, enables us to judge very well how vitriol is produced. But because this is usually reckon'd, with salt-petre, sea-salt, and sal-gem, among true salts; we must take notice, in the first place, that vitriol is not a mere salt, but what *Paracelsus*, and, after him, others call a magistery; which, in their sense, commonly signifies a preparation, wherein the body to be prepared has not its principles separated, as in distillation, incineration, &c. but wherein the whole body is brought into another form, by the addition of some salt or menstruum, united, *per minima*, with it. And accordingly, we find, that from common vitriol, whether native or factitious, may be obtained an acid, saline spirit, and a metalline substance; as copper may be separated from blue vitriol. And as there is a vitriol of iron, which is usually green, and another of copper, which is blue, and also a white vitriol, whose composition is generally unknown; yet all of these are, without scruple, reputed true vitriols, tho' they differ so much in colour, and several other qualities; so I see no reason, why the other minerals, being reduced, by their proper menstrua, into salt, like magisteries, may not pass for the vitriols of those metals, and, consequently, for natural bodies. If upon the filings of steel, we put a convenient quantity of oil of vitriol, and dilute the mixture with water, it is easy to obtain a vitriol of iron by crystallization; which fully agrees with the other vitriol, produced by nature without the help of any other menstruum, than rain water falling upon the marcasites. But that no scruple might arise from the menstruum used in making *vitriolum martis*, I employ'd a different one, that could not be suspected to have any thing of vitriol in it; and this was spirit of salt, which answered the same end. Nor will the great disposition in this our vitriol to resolve, by the moisture of the air, into a liquor, make it essentially different from other vitriols; since it has been observed, that even the common vitriol in *Germany*, will also run *per deliquium*. To apply these experiments, we may consider, first, that our factitious vitriol is not only endowed with many qualities common to other salts, as transparency, brittleness, solubility in water, &c. but such as are peculiar to it, as greenness, easiness of fusion, stypticity of taste, a peculiar shape, a power to strike a black with infusion of galls, an emetic faculty, &c. and, secondly, that tho' these qualities, are, in common vitriol, supposed to flow from

from the substantial form of the concrete, and may, as justly as the qualities of other inanimate bodies, be employ'd to prove such a form: yet, in our vitriol, made with spirit of salt, the same qualities were produced by the association of two ingredients, singly destitute of them; which enabled it to affect our organs of sense, and work upon other bodies, after the manner of common vitriol. Indeed, it is so far from appearing, that any substantial form is here generated a-new, that there is not so much as an exquisite mixture made: for both the ingredients retain their nature, and may easily be separated by distillation; so that there is here but a juxtaposition of the metalline and saline particles; only they are so associated, as by the manner of their coalition to acquire that new texture, which denominates the magistery they compose, vitriol.

But tho' the exact and curious figures, into which vitriol, and other salts, are apt to shoot, be made arguments of the presence, and great instances of the plastic skill of substantial forms, and seminal powers; yet, I am not so fully satisfy'd in this matter, as the modern philosophers appear to be. It is not that I deny *Plato's* $\gamma\epsilon\mu\alpha\iota\sigma\tau\epsilon\iota\varsigma\ \dot{\iota}\ \Theta\epsilon\delta\varsigma$, to be applicable to these exquisite productions of nature; for tho' God has thought fit, to make things after a more intelligible way, than by the intervention of substantial forms; and tho' the plastic power of seeds, seems unnecessary in our case; yet the divine geometry is, nevertheless, to be acknowledged, for having endowed the primary corpuscles of salts and metals, with a peculiar fitness for such concretions. And, tho' I see no necessity for ascribing such productions to a plastic power; yet, the more elaborate and curious fabric of animals, may be ascribed to an higher origin. But my conjectures about the figures of salts, will be supported by these considerations.

The curious figures of salts depend not upon substantial forms.

1. By a bare association of metalline and saline corpuscles, a concrete, as finely figured as other vitriols, is producible; as we have already shewn.

2. The figures of these salts are not constantly the same, but differently varied, as they happen to shoot more or less hastily, or in different proportions of liquor; as is manifest from the difference in crystals of vitriol, when large quantities are taken out of the great coolers. And, accordingly, where *Agricola* describes the several ways of making vitriol in large quantities, he compares the concretions indifferently to cubes, or clusters of grapes. I have so ordered a pure lixivium of alkalizate salts, from which used to be obtained only a white calx, that it has shot into transparent crystals, almost like white sugar-candy. And, having distilled a certain quantity of oil of vitriol, with a strong solution of sea-salt, the residue, dissolved in fair water, shot into crystals, sometimes of one figure, and sometimes of another, as the quantity and strength of the oil of vitriol, and other accidents, determin'd. From spirit of urine and of nitre, I have sometimes obtained, fine long crystals, shaped like salt-petre; and tho' silver, dissolved in *Aqua fortis*, or spirit of nitre, usually shoots into exceeding thin plates, almost like *Muscovy*-glass; yet, I have obtained lunar crystals, of a different figure; each crystal being composed

PHYSICS. of many small solids finely shaped, and adhering so fitly to one another, as to have one surface common to them all.

3. Insensible corpuscles of different exquisite shapes, and endowed with plain, smooth sides, will constitute bodies variously, but all very finely figured. And, first, tho' harts-horn, blood, and urine, may well be supposed to have their substantial forms destroy'd, by the action of the fire, in their analysis; yet their saline particles will leisurely shoot into crystals of very curious surfaces, and regular figures. And of these finely shaped crystals, of various sizes, I have obtained several from other distill'd acid liquors; and particularly, with a menstruum that would dissolve some gems, and with a solution of coral, made in spirit of verdigrease. For the same reason, when I try'd, whether the particles of silver, dissolved in *Aqua fortis*, would not, without coagulating with the salts, convene, upon account of their own shapes, into little concretions of smooth and flat surfaces; I found, that having diluted one part of the solution with a great many parts of distill'd rain-water, a plate of copper being suspended in the liquor, and suffered to lie quiet a while, there would settle about it, swarms of little metalline bodies, shining in the water, like the scales of small fish; but formed into little plates extremely thin, with surfaces not only flat, but exceeding glossy: and among those, several of the larger were prettily figured at the edges. And the corpuscles of gold are sufficiently disposed to convene, with those of fit salts, into concretions of determinate shapes; as I have found in the crystals obtained from it in *Aqua regis*: and, also, when, by a more powerful menstruum, I had subdivided the body of gold into such minute particles, as to be sublimable, these volatile particles, with the salts, wherewith they were elevated, afforded plenty of crystals, resembling one another in shape. I have, indeed, sometimes try'd to procure compound figures from the shootings of different salts together; but find, we must not expect, that in all cases, they should be totally compounded: for they often are of such different natures, that one will shoot much sooner than another; and then a large proportion of that will be first crystallized in its own shape, as is visible in refining impure, or *Barbary* nitre, from the common salt wherewith it abounds. And, as *Agricola* observes, where a vitriolate matter is mixed with alum, those two kinds of salt will shoot separately in the same vessel: in which cases, all that can be expected, is, that the remaining part of the mixture should afford crystals of compounded solid figures. Tho' the *Venetian* borax, sold in the shops, be a known factitious body, compounded of several salts; yet some of it being dissolved in a large quantity of fair water, and made to coagulate very leisurely, I thence obtained crystals, upon whose surfaces, I could perceive very exquisite and regular figures. We may add, that tho' the *Caput mortuum* of common *Aqua fortis* consists of bodies very different in nature; yet barely by frequent solutions and coagulations, the saline particles will shoot into very fine figures; as triangles, hexagons, rhomboids, &c. no less exact than those of the finest nitre or vitriol: some, moreover, terminate in bodies, almost like pyramids, consisting of several triangles, that meet in one point at the vertex, as admirably

rably shaped as the fairer sort of *Cornish* diamonds. And I have not only obtain'd new shapes by compounding saline bodies, such as sea-salt, and salt-petre, but found them, also, producible in some natural and chymical salts, dissolved together; and, also, in saline spirits made by distillation: but only those are fit for this purpose, which work upon one another with ebullition: for in that conflict, the saline corpuscles associate together, and, by their newly acquired figure, lose much of their former volatility; so that upon evaporation of the superfluous liquor, they will not fly away, as, otherwise, they might, but coagulate together into finely-shaped crystals; as I have tried with the spirits of urine and nitre, oil of vitriol, &c. And, what is farther remarkable, spirit of urine satiated with spirit of salt, has often afforded me crystals, exceedingly different in shape, from those obtained with spirit of urine, satiated, either with oil of vitriol, or with spirit of nitre. For that salt, compounded of the two spirits, of urine and of common salt, usually consists of one long rod, whence, on both sides, issue out far shorter crystals, sometimes perpendicular to that, and parallel to one another, like the teeth in a comb; and, sometimes, so inclining, as to make the whole appear, almost like a feather; which is the more remarkable, because I have observed sal-armoniac, made of crude urine and common salt, with a proportion of soot, will, if warily dissolved and coagulated, shoot into crystals of the like shape.

How far the unknown figure of a salt may possibly be guess'd at, by that of the figure, which it makes with some other salt, whose figure is already known, I leave others to discover.

4. Considering that vitriol was but a magistery, made by the coagulation of the corpuscles of a dissolved metal, with those of the menstruum; I thought the magisteries of other metals might, without inconvenience, be added, as other vitriolate concretes, to the green, the blue, and white vitriol, which are, without scruple, referred to the same species: but oil of vitriol being not a fit menstruum to dissolve several metals, nor even all those that it will corrode; and there being the like unfitness, also, in common spirit of salt, I pitch'd upon *Aqua fortis*, or spirit of nitre, as the menstruum, most likely to afford variety of vitriols; and, accordingly, found, that besides a curious one from copper, that liquor would, with quick-silver, afford one sort of crystals, with silver another, and with lead a third; all which crystals of vitriol, as they differ'd from each other in other qualities, so they did very considerably differ in shape; the crystals of silver shooting into exceeding thin plates, and those of lead and quick-silver obtaining figures, tho' different from each other, yet of a far greater depth and thickness, and less remote from the figure of common vitriol, or sea-salt: yet all these vitriols, especially that of crude lead, successfully made, had shapes curious and elaborate, as well as those we admire in common vitriol or sea-salt*.

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* Sir Isaac Newton gives the following account of crystallization. "When any sa-
K k 2 "line liquor is evaporated to a cuticle,
"and let cool, the salt concretes in regu-
"lar

PHYSICS.

If then these curious shapes, which are supposed the strongest proofs of substantial forms, may be the results of texture ; and if art can produce vitriol itself, as well as nature ; are not substantial forms unnecessary in solving the ordinary phenomena ; since matter, with a convention of accidents, is alone sufficient for that purpose ? And why should we wilfully exclude those productions of the fire, wherein the chymist is but a servant to nature, from the number of natural bodies ? Indeed, since there is no certain diagnostic agreed on, whereby to discriminate natural and factitious bodies, and constitute the species of both ; we might certainly draw arguments from the qualities and operations of several of those, which are called factitious bodies, to shew how much may be ascribed to, and performed by the mechanical characteristics or stamps of matter. And, if we admit these productions into the number of natural bodies, they will afford us a multitude of instances to shew, that bodies may acquire many noble qualities, barely, by having mechanical properties introduced by outward agents into their matter, or destroy'd there. Even those, who embrace *Aristotle's* principles, confess, that a slight change of texture, without the introduction of a substantial form, may not only make a specific difference betwixt bodies ; but so vast an one, that they shall have differing genus's, and (as the chymists speak) belong to different kingdoms. For coral, whilst it grows at the bottom of the sea, is a real plant, and hath often been there found soft, tender, and juicy ; it, also, propagates its species, as well as other shrubs ; yet, being gathered, and removed into the air, it turns to a stony concretion. And a much stranger thing may be seen in the island of *Sombrero* in the *East-Indies*, not very far from *Sumatra*, if we may believe *Sir James Lancaster*, who relates it as an eye-witness ; for which reason, I shall add the story in his own words. " Upon the coast of *Sombrero*," says he, " we found upon the sand, by the sea-side, a small twig growing up to a young tree ; and offering to pluck up the same, it shrunk down into the ground, and sinketh, unless you hold very hard. And being plucked up, a great worm is the root of it ; and look how the tree groweth in greatness, the worm diminisheth. Now as soon as the worm is wholly turned into the tree, it rooteth in the ground, and so groweth to be great. This transformation was one of the greatest wonders I saw in all my travels. This tree being plucked up a little, the leaves stripped off and the peel, by that time it was dry, turned into an hard stone, much like to white coral : so that this worm was twice transformed into different natures. Of these we gathered, and brought home many." *Pisc*, in his history of *Brasil*, appeals to a multitude of witnesses, for the ordinary transformation of a sort of animals, not much unlike grasshoppers, into vegetables, at a

lar figures ; which argues, that the particles of the salt, before they concreted, floated in the liquor at equal distances in rank and file, and, by consequence, that they acted upon one another by some power, which, at equal distances is equal, at unequal distances unequal. For by such a power, they will range themselves uniformly ; and without it, they will float irregularly, and come together as irregularly." *Newton's Optic*, p. 363.

certain

certain season of the year. And Father *Michael Boym* affirms, that he saw in a small shallow fresh-water lake of the island *Hainan*, (which belongs to *China*) crabs, or craw-fish, which, as soon as they were drawn out of the water, lost both life and motion in a moment, and became petrified; tho' nothing appeared to be changed, either in the external, or internal figure of their bodies.

S E C T. V.

HAVING dispatch'd the first argument, whereby I propos'd to confirm the origin of forms, from the manner, by which such a convention of accidents, as deserves to pass for a form, may be produced; I proceed to the second proof I design'd of the same, drawn from the re-production of a physical body. And this argument of the two is the most conclusive. For if we can re-produce a body, which has been deprived of its substantial form, it seems more than probable, that the form, which gives being and denomination to a concrete, may be, in some bodies, but a modification of the matter they consist of, whose parts, by a peculiar disposition to each other, constitute such a determinate substance, with particular properties; whereas, if the same parts were otherwise dispos'd, they would constitute other bodies of very differing natures from that of the concrete, whose parts they formerly were; and which may again result, or be produced after its dissipation, and seeming destruction, by the re-union of the same component particles, associated in their former manner. But tho' an adequate renewal of a body, chymically analyzed, be difficult, because of the dissipation of some parts in the process; yet such a re-production as is practicable, may suffice for our purpose. For even in such experiments, it appears, that by the bare re-union of some parts, the very same matter, without addition, may be brought again to constitute a body of the like nature with the former, tho' not of equal bulk.

Experiments to show the origin of forms, from the renewing of bodies.

In this manner we attempted the dissipation and re-union of the parts of common amber: and tho' chymists, for fear of breaking their vessels, when they commit it to distillation, add sand, brick-dust, &c. thereto, yet we found, that if the retort were not too full, and the fire slowly and warily applied, the addition of any other body was needless. Wherefore, having put into a glass-retort, four or five ounces of amber, and applied a gentle, gradual heat, we observed the amber to melt and bubble; and having ended the operation, and sever'd the vessels, there was come over, in the form of oil, spirit, phlegm, and volatile salt, near half the weight of the concrete: upon breaking the retort, we found in the bottom of it, a cake of coal-black matter, whose upper surface was so exquisitely polished, as to fit it to serve for a looking-glass; and this smooth mass being broken, the larger fragments appeared with an excellent lustre. All these parts of the amber, being again put together, into a glass-body, with a blind head luted to it, were placed in sand, to be incorporated by a gentle heat; but the fire having been rais'd too high, it forced the vessel out of the sand, and broke off the top,

PHYSICS. top. The remaining matter, resembling tar, was capable of being, with a gentle heat, poured out like a liquor; and, when cold, it would stick to the fingers: yet this opened body will not communicate so much as a tincture to spirit of wine; but with oil of turpentine, it dissolves into a blood-red balsam, useful, perhaps, in chirurgery.

In our attempts to renew vitriol, turpentine, and some other concretes, we found more difficulty, than every one would expect. The bodies, on which such experiments are likeliest to succeed, seem to be alum, sea-salt, and vitriol. Tho' we found it troublesome to take the principles of alum asunder, without a mixture of some foreign matter, which would hinder the restoration of the separated parts. So, likewise, if sea-salt be distilled, as usual, with thrice its weight of burnt clay, or beaten brick, that will prove inconvenient in its redintegration; and if it be distill'd alone, it is apt to flux by heat, and whilst it remains in fusion, will scarce yield any spirit at all. As for vitriol, tho' the redintegration of it might seem to be less hopeful, than that of the other salts, because it consists not only of a saline, but of a metalline body; yet, as there needs no *caput mortuum* in the distillation of it, we made two or three attempts, and seemed to miss rather upon account of accidental hindrances, than of any insuperable difficulty in the thing itself: for in our attempts to re-unite the liquors forced off by distillation, with the *caput mortuum*, we sometimes obtained shoots of pure vitriol. I likewise, digested, for several weeks, a quantity of powdered antimony, with a greater weight by half of oil of vitriol; and having committed this mixture to distillation, obtained, besides a little liquor a considerable quantity of combustible antimonial, or antimonio-vitriolate sulphur; there remaining at the bottom of the retort, a light, and very friable *caput mortuum*, all the upper part of which was as white as common wood-ashes, while the rest looked like a cinder. This *caput mortuum* we committed to a naked fire, in a small glass-retort, well coated, and accommodated with a receiver, for many hours; and, at length, disjoining the vessels, we found no antimonial quick-silver, and much less of sulphur sublimed than we expected. The *caput mortuum* was fluxed into a mass, covered with a thin cake of glass; fragments whereof being held against the light, were as colourless as common white glass. The lump above-mentioned being broken, was found to be perfect black antimony, adorned with long shining streaks, like common antimony; only this seemed to have been a little refined, by the sequestration of its unnecessary sulphur; which ingredient seems, by this experiment, to abound more in some particular parcels of that mineral, than is absolutely requisite to the constitution of antimony. But among all my trials, about the redintegration of bodies, that which seemed to succeed best, was made upon turpentine: for having taken some ounces of this, very pure, and good, and put it into a glass-retort, I distill'd it with a very gentle fire, till it was separated into a large quantity of very clear liquor, and a *caput mortuum*, very dry and brittle; then breaking the retort, I powdered the *caput mortuum*, which, when taken out, was transparent, exceeding sleek, and very red; but being powdered, appeared of a pure yellow colour.

This

This powder we carefully mixed with the liquor distill'd from it, which immediately dissolved part of it into a deep red balsam : but by farther digestion in a large glass exquisitely stopped, that colour began to grow fainter ; tho' the remaining part of the powder was perfectly dissolved, and so well re-united to the more fugitive parts of the concrete, that scarce any person, by the smell, taste, or consistence, would take it for other than good turpentine.

S E C T. VI.

THUS I have endeavoured to give the substance of the corpuscular philosophy, as far as is necessary towards understanding the productions and changes of particular qualities. And as these principles are built upon the phenomena of nature, and devised in order to explain them, I think proper to add, by way of recommendation thereof, such facts as led me to this doctrine, or as I was directed to discover by the notions I had embraced. And since I appeal to the testimony of nature, I shall set down some observations of what she does without assistance, and some experiments wherein she is guided by art. The observations will be the more suitable to our design, for being common and familiar ; and the experiments, for being few in number, and pregnant in phenomena.

1. The first observation shall be fetched from what happens in an egg, which undergoes very great changes, when it is by incubation turned into a chick. A prolific egg contains two liquors, each of them apparently similar : for tho' the white and the yolk seem to be dissimilar, by the different substances they afford in distillation ; yet it would be hard to prove, that one part of the white, for instance, will not be made to yield the same different substances by distillation, with any other part of the same : and bones themselves, with other hard parts of a human body, which are confessedly similar, will, by distillation, afford salt, phlegm, spirit, oil, and earth, as well as the white of an egg. Now, by bare concussion, this white may be reduced from a tenacious, to a fluid body : and the rudiments of the chick, lodg'd in the cicatricula, are nourished only by the white for some time ; the yolk being, by providence, reserved as a more solid aliment, when the creature is grown strong enough to digest it ; so that we may see the chick furnished with head, wings, legs, beak, claws, &c. whilst the yolk appears untouched. But whether this observation about the entireness of the yolk, be precisely true, it is not very material ; since the yolk itself, being, likewise, a similar fluid, is sufficient for the present purpose. Now, the nutritive liquor of an egg, being brooded on by the hen, will, within two or three weeks, be transmuted into a chick, furnished with organical parts, as eyes, ears, wings, legs, &c. of a very differing fabric ; and with a great number of similar ones, as bones, cartilages, ligaments, tendons, membranes, &c. which differ much in texture from one another ; besides the liquors, as blood, chyle, gall, &c. contained in the solid parts. In a word,

PHYSICS. we have here produced, out of such an uniform matter, as the white of an egg, first, many new kinds of qualities, as colours, odours, tastes, heat, hardness, smoothness, roughness, &c. secondly, qualities usually distinguished from sensible ones, as fluidity, consistence, flexibility, springiness, &c. and, thirdly, occult properties, since, as physicians observe, some birds afford specific medicines in the falling-sickness, hysteric fits, and other distempers.

If it be here alledged, that the chick, with all its parts, is not an engine mechanically contriv'd, but fashion'd out of matter by the soul of the bird, lodged chiefly in the cicatricula, which by its plastic power fashions the obsequious matter, and becomes the architect of its own mansion; I answer, that this invalidates not what I intend to prove from it: for, let the plastic principle be what it will, yet being a physical agent, it must act after a physical manner; and having no other matter to work upon, but the white of an egg, it can, consequently, only divide the matter into minute parts of several sizes and shapes, and, by local motion, variously context them, according to the exigency of the animal to be produced; tho' from so many various textures of the produced parts, there must naturally result various differences of colours, tastes, consistences, and many other qualities. We are here to consider, not what is the agent, or efficient, in these productions; but what is done to the matter that affords them. And tho' some birds, by an inbred skill, very artificially build their nests; nature only enables them to select the materials thereof, and, by local motion, to divide, transport, and connect them after a certain manner. And, when man himself, who is, undoubtedly, an intelligent agent, is to raise a building, or form an engine, he may, indeed, by the help of reason and art, skilfully contrive his materials; still, all he can do, is but to move, divide, transpose, and set together the several parts, into which he is able to reduce the matter assigned him. Nor need we imagine, that the soul of that hen, which having first produced the egg, after a while sits on it, hath any peculiar efficiency in hatching of a chick; for the egg might be as well hatch'd by another hen, tho' that which laid it were dead: nay, in some places, especially in *Ægypt*, there needs no bird at all to produce a chick out of an egg, where multitudes of eggs are hatch'd by the regulated heat of ovens and dunghills.

2. Water being esteemed an elementary body, and far more homogeneous than any other fluid; it will make very much for our purpose, to shew, that by a different texture of its parts, it may be brought to constitute bodies of very different qualities. And this it does by nourishing vegetables: for thus all, or the greatest part, of that which would accrue to a vegetable so nourished, appears to have been materially water; with what foreign quality soever it may afterwards, when transmuted, be endowed. *Helmont* mentions an experiment of this nature, made with a willow, set in a pot of earth, which for several years he fed with rain-water. And we may conjecture at the easy transmutableness of water, by what happens in gardens and orchards,

chards, where the same showers of rain, after a long drought, cause a great number of differing plants to flourish. But these things do not fully reach our case, because it may be objected, that rain-water causes not these plants to thrive and flourish, by immediately affording them the aliment they assimilate into their own substance; but by proving a vehicle to the saline substances of the earth, itself being insensibly, afterwards, exhaled in vapour. And, indeed, experience shews us, that several plants, which thrive not well without rain-water, are not yet nourished by it alone; since when corn and fruit-trees have consumed the saline and sulphureous juices of the earth, they will not prosper there, how much rain soever falls upon the land, till by dung or otherwise, it be again supplied with proper juices. Wherefore I attempted to make plants grow in vials fill'd with nothing but water; and found, that *vinca pervinca*, *raphanus aquaticus*, spear-mint, and even *ranunculus*, grew and prosper'd very well therein; yet some of these were only slips without roots. Several were left in the water all the autumn, and a great part of the winter; and at the end of *January*, were taken out green, and with fair roots, which they had shot in the water: particularly a branch of *raphanus aquaticus*, was kept full nine months; and during that time withered not, tho' it pass'd the whole winter; and was taken out with many fibrous roots, some green buds, and an increase of weight. A stump of *ranunculus* prospered in the water so, that, in a month's time, it attained to more than double the weight it had when first put in. And another piece of *ranunculus* being taken out six months after it was put in, weighed almost a dram and an half, which was above thrice as much as it did at first: and this circumstance demonstrates a real assimilation and transmutation of water into the substance of the vegetable. Hence I infer, that the same corpuscles, which, convening together after one manner, compose that fluid, inodorous, colourless, and insipid body, water, being ranged after a different manner, may constitute different concretes, possess'd of firmness, opacity, odours, tastes, colours, and several other manifest qualities; and these too very different from one another. Besides, these distinct portions of transmuted water may have many other qualities, without excepting those, which are called specific or occult; witness the several medicinal virtues attributed to spear-mint, to *vinca pervinca*, marjoram, and *raphanus aquaticus*. If it be here pretended, that the solid substance accruing to a plant in water, proceeds not from the water itself, but from the nitrous, fat, and earthy substances, which may be presumed to abound, even in common water; I reply, that, tho' as to several plants, which flourish after rain, I am apt to think, they may in part be nourished, as well by the saline and earthy substances, to which the rain usually proves a vehicle, as by the rain itself; yet as to plants which grow in glasses filled with pure water, this should not be barely asserted, but proved*; which,

* Dr. Woodward has made several curious experiments, to shew, that mere elementary water will not suffice for the vegetation of plants; but that a terrestrial matter contain'd in, and, by repeated filtration,

distillation, &c. not wholly separable from its vehicle, water, is absolutely necessary thereto. See *Philos. Trans.* N° 253. p. 193-207.

perhaps, is not easy to be done, considering how vast a quantity of fair water must be exhaled away, to obtain even an ounce of dry residue, whether saline or earthy.

3. That a plant growing in the earth doth attract, by virtue of its vegetative soul, the juices of the earth within its reach, and selecting the parts agreeable to its nature, refuse the rest, is the general opinion; and, therefore, many are not surprized, when a tree bears fruit, that is sour or bitter, because they presume, nature, in the root of the tree, has culled out such parts of the alimental juice of the earth, as, convening into fruit, are fit to give it such a quality. But it is worth observing, for our present purpose, what happens, both in ordinary graftings, and especially in inoculation: for tho' we may presume, that the root of a white-thorn, may electively attract its aliment from the earth, to produce the fruit, which is proper to it; yet we cannot suppose, that it should, in its attraction of aliment, have any design of providing an appropriate nutriment for a pear: but, we know, that the cions of a pear-tree will take very well upon a white-thorn-stock, and yield fruit, very different, in many qualities, from that of the white-thorn. And, tho' apples and pears are seldom propagated but by grafting, yet they may be so by inoculation; which seems to be but a kind of grafting with a bud. Now, in the inoculations, made upon fruit-trees, it is observable, that a little vegetable bud, often not so big as a pea, is able so to transmute all the sap which arrives at it; that, tho' this sap be already in the root, and, in its passage upwards, determined by nature's intention, as men speak, to the production of fruit, natural to the stock; it should yet, by so small a vegetable substance, be so far changed, as to constitute a fruit quite otherwise qualified, than the genuine product of the tree; which, at the same time, is actually produced by those other portions of the like sap, that happened to nourish such prolific buds, as are the genuine off-spring of the stock: so that the same sap, which, in one part of a branch, constitutes a cluster of haws, in another part of the same branch, may constitute a pear. And, what is farther remarkable, not only the fruits made of the same sap, often differ from one another, in shape, bigness, colour, odour, taste, and other obvious qualities; but tho' the sap itself, be a waterish, and, almost, insipid liquor; yet it is not only convertible, by buds of several natures, into different fruits, but in one and the same fruit, the transmuted sap, shall, by different textures, be made to exhibit very different, and sometimes contrary qualities. As when a peach-bud not only changes the sap, which comes to it, into a fruit, very differing from that, which the stock naturally produces; but into parts very different from one another in the same fruit. From inoculations, therefore, we learn, that a liquor seemingly homogeneous, may, by being variously strain'd, be transmuted into bodies, endowed with new scents, colours, tastes, solidity, medicinal virtues, and many other qualities, manifest and occult. If it be said, that these qualities are the productions of the plastic power, residing in prolific buds, the same answer will serve, as to the like objection in the first observation.

4. The last observation I shall, at present, mention, is, of rotten cheese: for if we take notice of the difference betwixt two parts of the same cheese, whereof the one continues sound, by preserving its texture, whilst the other hath suffered that alteration we call rottenness; we may, often, see a manifest change in the several portions of a body, which was before similar; for the rotten part will differ from the sound in its colour, its odour, its taste, and several other qualities: and if, with a good microscope, we view the mouldy parts of some cheeses, we shall discover therein swarms of little animals, furnished with variety of parts of different sizes, shapes, textures, &c. and perceive a yet greater diversity, as to manifest qualities, betwixt the mouldy part of the cheese, and the untainted, than were visible to the naked eye.

S E C T. VII.

WE come now to our experiments about qualities.

1. Into good clear oil of vitriol, throw a convenient quantity of camphire, grossly beaten, and, after a while, it will run into a liquor; and, by shaking, mix with the oil; as, also, impart thereto, first a yellow, then a red colour, and, at last, bring it to be opaque and scentless: but, if into this liquor, be poured a due proportion of fair water, it immediately becomes pale, and the camphire emerges in its own nature and form, white, combustible, and odorous.

Experiments to shew the nature of qualities: and first, camphire suddenly restored, after it seem'd to be destroy'd.

The phenomena of this experiment afford us several particulars to our present purpose. (1.) We here see a light consistent body, brought, by comminution, to swim and mix with a heavy liquor, on which it floated before; but as gold dissolv'd in *Aqua regia*, is thereby kept from sinking, these instances, compared together, shew, that when bodies are reduced to very minute parts, we must as well consider their particular texture, as the received rules of hydrostatics, in determining whether they will sink, or float. (2.) This experiment also shews, that several colours, and even a very deep one, may sometimes be produced by a white body, and a clear liquor; and that without the intervention of fire, or any external heat. (3.) That this colour may be destroy'd, and the whiteness restored by the addition, only, of fair water; which, also, receives neither the colour it destroy'd, nor that it restored. For, (4.) the opacity of the solution presently vanishes, and that menstruum, with the water, makes up (as soon as the corpuscles of the camphire come to float) one transparent liquor. (5.) It is also worth noting, that upon the mixture of a liquor, which renders the whole much lighter, a body is made to emerge, that did not so before. And here I cannot but observe, how little the school-distinction, of elements losing their forms in mixed bodies, is favoured by this experiment; wherein even a mixed body (for such is camphire) doth, in a farther mixture, retain its form and nature, and may be immediately so divorced from the body, to which it was united, as to return, in a moment, to the manifest exercise of its former qualities. (6.) But the notablest thing in the experiment,

PHYSICS.

ment, is, that odours should depend so much upon texture ; that one of the strongest-scented drugs, should quite lose its scent, by mixing with a body that hath none of its own. (7.) Nor is it less considerable, that so strong a scent should be produced in a mixture, wherein none could be perceived before, by such a liquor as water ; which is quite destitute of any odour. And so easy a restoration of the camphire to its native scent, as well as other qualities, likewise argues, that the union or texture of the two ingredients, the camphire and the oil of vitriol, was but very slight ; upon which, nevertheless, a great alteration, in point of qualities, ensues. And to confirm that several of the preceding phenomena depend upon the particular texture of the liquors here employ'd, it may be observed, that if instead of oil of vitriol, spirit of nitre be made use of ; not a red or dark, but a transparent and colourless solution will ensue. And when to the above-mentioned red mixture, I put, instead of fair water, about two or three parts of duly rectified spirit of wine, there would follow no such changes ; but the spirit of wine, that acquires no colour by dissolving the concrete apart, yet took out of the mixture its adventitious colour, which subsisted not before in either ingredient. But by prosecuting the experiment a little farther, we made it afford us some new phenomena. For, (8.) having kept the mixture in a warm place, and distill'd it out of a glass-retort, the liquor which came over, had a strong scent, quite different both from that of the mixture and the camphire ; the remaining mass being coal-black, and some of its parts looking like polished jet : which is the more considerable, because tho' vegetable substances usually acquire a blackness from the fire ; yet, neither liquors that have already been distill'd, obtain that colour upon redistillation, nor have we, upon trial, found, that camphire exposed to the fire in a retort, fitted with a receiver, would at all acquire a jetty colour. (9.) We farther learn by this experiment, that notwithstanding the great volatility of camphire, yet here it is so restrained, that the *caput mortuum*, just mentioned, endured a strong fire in the retort, before it was reduced to that pitchy substance : and, afterwards, bore a much stronger, for above half an hour, in a covered crucible, without yielding any scent : so much do the fixity and volatility of bodies depend upon texture.

Changes made
by sublimate
upon copper.

2. Among many experiments made with sublimate, to manifest, that new qualities are producible in bodies, as the effects of new textures, I shall here only produce such wherein copper, silver, and gold, were used. And, first, we took half a pound of copper-plates, each about an inch broad, and of the thickness of a grain of wheat, and of any length ; then casting a pound of grossly-beaten *Venetian* sublimate into the bottom of a deep glass-retort, we placed the copper-plates upon it, that the fumes of the sublimate might, in their ascent, act upon the metal ; and fixing this retort deep in a sand-furnace, and adapting to it a small receiver, we gave it a gradual fire for seven or eight hours, and at length increased the heat. The success was, (1.) there came little or no liquor over, but the neck and upper part of the retort were candied on the inside, by the sublimate adhering to them, in quantity above ten ounces ; and in the retort, we found two ounces and

a quarter of running mercury. (2.) Upon increasing the fire, the melting matter made a noise in the retort, not unlike that of a boiling pot; and this we found to be a more constant circumstance, than the revival of the mercury; for upon another trial, with the former proportions, we found but a few grains of it either in the retort or receiver. (3.) The metalline lump at the bottom of the retort increased in weight above two ounces; some of the copper-plates, lying at the bottom of the mass, yet retained their figure, and malleableness; which we ascribed to their not having been thin enough, to be sufficiently wrought upon by the sublimate: the others, which were much the greater number, had wholly lost their metalline form, and were melted into a very brittle lump, which I can compare to nothing more fitly than a lump of good benjamin: for this mass, tho' ponderous, was no less brittle, and being broken, appeared of various colours, which seemed to be almost transparent, and in some places it was red, in others of a high amber colour, and in others again, darkish and mixed. (4.) But this mass being broken into smaller lumps, and laid upon a sheet of white paper in a window, was, by the next morning, covered with a lovely greenish blue, almost like that of the best verdigrease; and the longer it lay in the air, the more of the internal parts of the fragments passed into the same colour: but the white paper, which, in some places they stained, seemed dyed of a green colour, inclining to yellow. (5.) In some trials we observed, that little copper-plates, from which the sublimate had been drawn off, retain'd their shape and metalline nature, but were whitened over like silver, and continued so for several months; and upon breaking them, we found this silver colour had penetrated quite through them, and appear'd more beautiful in the very body of the metal, than on its surface. (6.) In this metalline gum, the body of the copper appeared so changed, and opened, that when cast upon a coal, and a little blown, it would partly melt and flow like rosin, and partly flame and burn like sulphur; and so inflammable was it, that held to a candle, or a piece of lighted paper, it would, almost in a moment, take fire, and flame like common sulphur; only it seemed to incline more to a greenish colour.

We next made the experiment with sublimate and silver; wherein were *Upon silver.* taken of the purest coined silver, ten thin plates, on which we cast double the weight of sublimate, in a small and strongly-coated retort. This matter being sublimed in a naked fire, we found the sublimate almost totally ascended to the top, and neck of the retort; in the latter of which appeared some revived mercury: at the bottom of the retort, was found a little fluxed lump of matter, which it was scarce possible to separate from the glass; but having, with much ado, divorced them, we found it brittle, of a pale yellowish colour, about the weight of the metal on which the sublimate had been cast; and in the thicker part of this lump, there appeared, when broken, some part of the silver plates, which, tho' brittle, seemed not to have been perfectly dissolved. This rosin of silver, did, like that of the copper, but more slowly, imbibe the moisture of the air; and within about twenty four hours, was covered with a greenish dust: some small fragments of

PHYSICS.

of this rosin being cast upon red-hot coals, wasted themselves in a flame, not very different, in colour, from that of the rosin of copper, but proved more durable, than one would have expected from so small a quantity of matter. But suspecting that the copper, usually mixed as alloy with our coined silver, might have too much influence here, we afterwards try'd it with refined silver, which but little altered the success. And it is remarkable, as silver is a fixed metal, and accounted indestructible, that it should, by so slight an operation, and with so small an addition of other matter, be so strangely disguised, and have its qualities so altered. For, first, tho' pure silver and sublimate, are both eminently white, yet the mass we are speaking of, was partly of a lemmon or amber colour, or a deep amethystine, and partly of so dark an one, that it appeared black; and sometimes in a fragment, which seemed to be one continued piece, the upper part would be of a light yellow, and the lower very obscure, and almost black. Next, whereas silver is one of the most opaque bodies in nature, and sublimate a white one, the produced mass was, in a great part, transparent, like good amber. Thirdly, the texture of the silver was exceedingly altered; for instead of being flexible, it appeared like horn, and more apt to crack and break, than bend. Fourthly, tho' silver will long endure the fire before it be brought to fusion, our mixture would easily melt, not only upon quick-coals, but in the flame of a candle; tho' this rosin, or gum of our fixed metal, did not, like that of copper, tinge the flame of a candle, or produce, when laid on glowing coals, either a green or bluish colour.

And upon gold.

But farther to discover how much these operations of the sublimate on copper and silver depend upon the particular texture of the bodies, I took two parcels of gold, the one common, in thin plates, and the other very well refined; and having cast each of these into a distinct urinal, upon no less than thrice its weight of grossly-beaten sublimate, I caused the sublimate to be, in a sand-furnace, elevated from the gold; but found not, that either of the two parcels of that metal was manifestly altered thereby: whether in case, the gold had been reduced to very minute particles, some kind of change might have been made in it, I will not say; but am confident, that these operations depend very much upon the particular texture of the body, from whence the sublimate is elevated. Such experiments may probably be farther improved, by employing various and new kinds of sublimate. And to shew that several other things may be sublimed up together, either with crude mercury, or with common sublimate, this instance may be added. Having caused about equal parts of common sublimate, and sal-armoniac to be well powdered, and incorporated; by subliming the mixture in strong and large urinals, placed in a sand-furnace, we obtained a new kind of sublimate, differing from the former: for dropping a little resolved salt of tartar upon the solution of common sublimate, it immediately turns of an orange-tawny colour; but dropping the same liquor upon the solution of the armoniac sublimate, it presently changed into a liquor resembling milk. And having, from four ounces of copper-plates, drawn six ounces of this new sublimate, after the aforesaid manner, we had in the bottom of the re-

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sort a cupreous rosin, not much unlike that made by copper and common sublimate; and this rosin, did, like the other, begin, in the moist air, soon to degenerate into a kind of verdigrease: but it was singular in this operation, that not only some of the sublimate had carried up, to a considerable height, enough of the copper to be manifestly coloured by it, of a fine bluish green; but into the receiver there was passed near an ounce of liquor, which smelt almost like spirit of sal-armoniac, and was tinged like the sublimate: yet I judged not this way the most effectual for improving common sublimate; being apt to think, that it may, by convenient liquors, be so far advanced, as to be made capable of opening the body of gold itself, and produce it in such changes, as chymists often in vain attempt.

3. Another experiment to shew how the like qualities in bodies may be produced by different ways, provided a like change of texture be made by them, we have from the process of the *Luna cornea*; in which we take refined silver, beaten into thin plates, and dissolving it in about twice its weight of good *Aqua fortis*, filtrate the liquor carefully to obtain a clear solution: into this we drop good spirit of salt, till it will no more curdle; then putting the whole mixture in a glass-funnel, lined with cap-paper, and letting the moisture drain through, we dry, with a gentle heat, the substance that remains in the filtre; first washing it from the loosely-adhering salts, by letting fair water run through it several times, whilst it yet continues in the filtre. This substance, being well dried, we put into a glass vial, which we set upon quick-coals, first covered with ashes, and then freed from them, and melt the contained substance into a mass, which kept for a while in fusion, gives us the *Luna cornea*. If we first reduce the silver into crystals, and afterwards proceed with spirit of salt, in the manner described, we have the exceedingly opaque, malleable, and hardly fusible body of silver, by the convenient interposition of some saline particles, not amounting to the third part of the weight of the metal, reduced into crystals, which both shoot in a peculiar and determinate figure, differing from those of other metals, and are, also, transparent and brittle, and much more easily fusible, than silver itself; not to mention other qualities.

Here we observe, (1.) That tho' spirit of salt be an highly acid liquor; and tho' acid liquors and alkalies have quite contrary operations, the one precipitating, what the other would dissolve, and dissolving what the other would precipitate; yet, in this case, as neither oil of tartar *per deliquium*, nor spirit of salt will dissolve silver; so, both the one and the other, precipitate it: which may pass for a proof, that the precipitation of bodies depends not upon acid or alkali, but upon the texture of the bodies, which happen to be mixed. (2.) We here find, that whiteness and opacity may be immediately produced by liquors, both of them transparent and colourless. (3.) That a white powder may, by a gentle heat, be reduced into a mass, indifferently transparent, and of a fair yellow. (4.) That tho' silver requires so strong a fire to melt it, and may be long kept red-hot, without being brought to fusion; yet, by the association of some saline particles, conveniently mixed therewith, it may be made so fusible, as to be quickly melted,

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PHYSICS.

either in a thin vial, or at the flame of a candle, where it will flow almost like wax. (5.) It may, also, be noted, that tho' the solution of silver, and the spirit of salt, would, either of them a-part, have readily dissolved in water; yet, when they are mixed, they, for the most part, coagulate together into a substance, which will lie undissolved in water; and is scarce soluble either in *Aqua fortis*, or spirit of salt. (6.) It is remarkable, that the body of silver being very flexible, and malleable, it should yet, by the addition of so small a proportion of salt, be made of a texture so different from that of either of its ingredients; being wholly unlike, either a salt or a metal, and very like in texture to a piece of horn. And to satisfy myself how much the toughness of this metalline horn depended upon the texture of the composition, resulting from the respective textures of the several ingredients, I precipitated a solution of silver with the distill'd saline liquor, commonly called oil of vitriol, instead of spirit of salt; and having washed the precipitate with common water, I found, that by being fluxed in a moderate heat, it afforded a mass, in appearance, like the concrete we are speaking of; but wanting its toughness, being brittle enough to be easily broken. (7.) And tho' a solution of silver is the very bitterest of liquors, and the spirit of salt far sourer than the sharpest vinegar; yet these two liquors are soon easily reduced into an insipid substance; notwithstanding the salts, which made both the silver, and the precipitating spirit so strongly tasted, remain associated with the metal. And, lastly, it is very strange, that tho' the saline corpuscles, which give the efficacy both to *Aqua fortis*, and to spirit of salt, are not only so volatile, that they will easily be distilled with a moderate fire, but so fugitive, that they will in part fly away of themselves in the cold air; yet, by virtue of the new texture they acquire, in associating themselves with the corpuscles of the silver, they obtain a sufficient degree of fixedness to endure melting with the metal. Nor in melting this mass in a thin vial, could I perceive any sensible evaporation of the matter: nay, having afterwards put a parcel of it upon a quick coal, it suffered fusion, and ran off, without appearing to be other than *Luna cornea*, as it was before.

Unusual phenomena of a new and surprising salt.

4. I shall next produce the phenomena arising in the process of a salt, which, contrary to my custom, I must conceal. And, first, tho' the several ingredients of this salt were purely saline, and more so than brine, or sourer than the strongest vinegar; yet the compound is so far from being eminently salt, sour, or insipid, that it is rather sweet, than of any other taste; tho' its sweetness be of a peculiar kind: and this is the only instance, I remember hitherto to have met with of salts, which compose a substance really sweet. Farther, tho' its odour be not strong or offensive, yet if it be urged with heat enough to evaporate it hastily, it emits a stench, more insupportable than that of *Aqua fortis*; yet, when these fumes settle again into a salt, their odour will again prove mild, and inoffensive, if not pleasant. Thirdly, tho' all the known volatile, acid, and lixivate salts, may be destroy'd by one another; as spirit of urine mixed with spirit of salt, or *Aqua fortis*, will make great ebullition, and lose its peculiar taste, and several of its other qualities; and as salt of tartar, and other alkalies, will be destroy'd, with ebullition,

tion, by *Aqua fortis*, spirit of salt, or almost any other strong spirit of that family; and tho' spirit of salt, and *Aqua fortis* will be destroy'd, both by animal volatile salts, and by the fixed salts of vegetables: yet our salt seems above being thus wrought upon by any of the three; and is the only body I know, which would not fret, either with oil of tartar *per deliquium*, spirit of sal-armoniac, strong spirit of salt, or oil of vitriol. But this is not the only way I try'd it; for I found, that it would not turn syrup of violets either red, as acid spirits do, or green, as both fixed and volatile salts will; nor would the strongest solution of it change a clear one of sublimate in common water, either white, as spirit of urine, sal-armoniac, or others of the same family; or into an orange-tawny, like salt of tartar, and other alkalies; but left it transparent. In conjunction, however, with spirit of salt, it would turn syrup of violets, red; and, with oil of tartar, green: which seemed to argue, that tho' our solution, as to sense, was exquisitely united in the several mixtures, it left them their respective natures undestroy'd, and retain'd its own: and yet this salt is so far from being languid, that *Aqua fortis*, and oil of vitriol themselves, are, in many cases, unable to make solutions, and perform other things like it, as a menstruum. Lastly, tho' this salt be volatile of itself, yet dissolved in liquors, it will even boil, without subliming, before the liquor be almost totally drawn off; whereas, the volatile salt of urine, blood, harts-horn, &c. ascend, before almost any part of the liquor they are dissolved in. And tho' this be volatile, yet I remember not, that any fixed salt will run near so soon *per deliquium*; but by abstraction of the adventitious moisture, it is easily restored to its saline form; nevertheless, it differs from salt of tartar, not only in fixedness, taste, and other qualities; but, also, in this, that whereas salt of tartar requires a vehement fire to flux it, a more gentle heat, than one would easily imagine, will melt our salt into a limpid liquor. And, whereas spirit of wine will dissolve some bodies, and water many, which spirit of wine cannot, and oils will dissolve some, for which neither of the other liquors are fit; our salt readily dissolves both in fair water, in the highest rectified spirit of wine, and in chymical oils themselves.

5. Our next experiment will shew what great changes may be effected by the recess of some particles, the access of others, and the new texture of the residue, even in inanimate, and scarce corruptible bodies. Take one part of good sea-salt, well dried and powdered, and put to it double its weight of good *Aqua fortis*, or spirit of nitre; then having kept it for some time in digestion, distil it with a slow fire in a retort, till the remaining matter be quite dry, and no more; for the substance, that will remain in the bottom of the glass, is the thing sought for.

A transmutation wrought upon saline bodies supposed almost indestructible.

As to the changes hereby effected, we may first take notice, that the liquor, which came over, was no longer an *Aqua fortis* or spirit of nitre, but an *Aqua regis*. 2. The taste of the remaining substance comes, by this operation, to be very much altered; for it retains not that strong saltiness it had before, but is far milder. 3. Whereas common salt is a body of very difficult fusion, our factitious salt imitates salt-petre in being very fusible, and will,

PHYSICS.

like that, soon melt, by being held in the flame of a candle. 4. But a more considerable phenomenon is, that, tho' sea-salt very much resists the fire; and tho' the acid spirits of salt, vitriol, nitre, vinegar, &c. are not only un-inflammable themselves, but hinderers of inflammation in other bodies; yet small lumps of this substance, cast upon quick coals, burnt away with a large and vehement flame: and, upon farther trial, having melted a considerable quantity of this transmuted sea-salt in a crucible; by casting upon it little fragments of well-kindled charcoal, it would, like nitre, presently blaze bright. Nor were all its inflammable parts consumed at one deflagration; for by casting in more fragments of well-kindled coal, the matter would puff, and flame afresh, for several times, according to the quantity which had been put into the crucible. 5. This suggested a hint of turning an acid salt into an alkali, which seems to be one of the greatest changes, that can be attempted, by reason of the vast difference there is between them in abundance of respects. Accordingly, having cast in several bits of well-kindled coal, and excited in the melted mass of our transmuted salt, as many deflagrations as I could; and then giving it a strong fire, to drive away the rest of the more fugitive parts, I found it to taste, not like sea-salt, but fiery upon the tongue, and to have a lixivate relish. I found too, that it would turn syrup of violets greenish; that it would precipitate a limpid solution of sublimate, made in fair water, into an orange-tawny powder; that it would, like other fixed salts, produce an ebullition with acid spirits, and even with spirit of salt itself, and con-coagulate with them. I, indeed, consider'd at first, that this new alkali might proceed from the ashes of the injected coals: but when I reflected too, that a pound of charcoal, burnt to ashes, yield so very little salt, that the injected fragments of coal, quite burnt out in this operation, would scarce have afforded two or three grains of salt; I concluded, that so considerable a proportion of ashes, in the whole mass, could not exhibit all the phenomena of an alkali. And, for farther confirmation, I poured upon a quantity of this lixivate salt, a due proportion of *Aqua fortis*, till the hissing and ebullition ceased; and then leaving the fluid mixture to coagulate, which it did very slowly, I found it, at length, to shoot into saline crystals, which, tho' not of the figure of nitre, yet, by their inflammability and magnitude, sufficiently argued, that there had been a conjunction made betwixt the nitrous spirit, and a considerable proportion of alkali. I consider'd, also, it might be said, that in our experiment, the nitrous corpuscles of the *Aqua fortis*, lodging themselves in the little spaces deserted by the saline corpuscles of the sea-salt, that passed over into the receiver, had afforded this alkali; as common salt-petre, being treated in such a manner, would leave in the crucible a fixed or alkalizate salt: but, as the sea-salt, which was not driven over in so mild a distillation, and seemed a much greater part than that which had passed over, was far from being of an alkalizate nature; so the nitrous corpuscles, presumed to have staid behind, were, whilst they composed the spirit of nitre, of an highly volatile, and acid nature, and, consequently, directly opposite to that of alkalies; and if, by the addition of any other substance,

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no more an alkali than sea-salt, an alkali could be obtained out of spirit of nitre or *Aqua fortis*, the producibleness of an alkali out of bodies of another nature, might be rightly thence inferred; so that two substances, formerly acid, are here turned into one, manifestly of an alkalizate nature. But, farther, to prosecute the experiment, by inverting it, we drew two parts of strong spirit of salt from one of purified nitre; but did not observe the remaining body to be any thing near so considerably changed as the sea-salt, from which we had drawn the spirit of nitre; since, tho' the spirit of salt, which came over, brought so many of the corpuscles of the nitre with it, that being heated, it would readily dissolve leaf-gold; yet the salt that remained in the retort, being put upon quick coals, flash'd away with a vehement, and flatulent flame, very like that of common nitre.

6. In attempting to make and improve the *Sal mirabile* of Glauber, I drew off from a solution of nitre, and oil of vitriol, a good *Spiritus nitri*; which, even before rectification, would dissolve silver, tho' it were diluted with as much common water, wherein salt-petre had been dissolved, as amounted, at least, to double or treble the weight of the nitrous parts: the remaining matter being kept in the fire, till it was dry, afforded a salt easily reducible, by solution in fair water, and coagulation, into crystalline grains, of a nature very different both from crude and fixed nitre, and from oil of vitriol. Besides, these crystals would not flow in the air, like fixed nitre, and were easily fusible by heat; whilst fixed nitre usually requires a vehement fire to fuse it: and tho' crude salt-petre, also, melts easily; yet, to see how different a substance this of ours was from that, we cast quick coals into the crucible, without being at all able to kindle it. And when, for farther trial, we threw in some sulphur, also, tho' that flam'd away itself, yet it did not seem to kindle the salt, which was hot enough for that purpose; much less did it flash, as sulphur usually makes salt-petre do. To all which we may add, that a parcel of this white substance, being, without brimstone, made to flow for a while in a crucible, with a piece of charcoal, for it to work upon, it became strongly scented of sulphur, and acquired an alkalizate taste; so that it seemed almost a coal of fire upon the tongue, when licked, before it imbibed any of the air's moisture; and obtained, also, a very red colour: which re-called to my mind, that *Glauber* mentions such a change observable in his salt made of common salt; upon which account, he calls such a substance his *Carbunculus*.

Here we may, first, take notice of the power of mixture, in altering the nature and qualities of the compounding bodies. For, in this case, tho' sea-salt requires a naked fire to elevate it; yet the saline corpuscles are distill'd over in a moderate heat of sand; whilst the oil of vitriol, by whose intervention, they acquire this volatility, tho' it be not a gross corporeal salt, but a liquor, which hath been already distill'd, is, by the same operation, so fixed, as to stay behind. Nor is the oil of vitriol, only, thus far fixed, but otherwise, also, no less changed: for, when the remaining salt has been exposed to a competent heat, that it may be very dry and white, you shall obtain a substance, not at all tasting of sea-salt, or having the pun-

PHYSICS. gency or acidity of oil of vitriol. A second particular, here remarkable, confirms what I formerly intimated, that, notwithstanding the regular and exquisite figures of some salts, they may, by the addition of other bodies, be brought to constitute crystals of very differing, yet curious shapes. For if you dissolve this *Caput mortuum* of sea-salt, in a sufficient quantity of fair water, and having filtrated the solution, suffer the dissolved body leisurely to coagulate; you will obtain crystals of a far greater transparency, than the cubes into which sea-salt shoots, and of a shape far differing from theirs, tho', often, no less curious than that of those cubes: and, what is very remarkable, I have often observed, those finely-figured crystals to differ as much in shape from one another, as from the grains of common salt. And, indeed, I must own, that, whether we impute it to the peculiar nature of sea-salt, or to the great disparities to be met with in liquors, that pass for oil of vitriol, my attempts to make the best sort of *Sal mirabile*, have been subject to so much uncertainty, that I reckon this experiment amongst such as are contingent.

The transmutability of metals proved experimentally, by converting gold into silver.

7. The following experiment, supposes metals, as well as other bodies, to be made of one universal matter, common to them all; and to differ but in the shape, size, motion or rest, and texture of the small parts they consist of; whence the qualities, which diversify particular bodies, result; and, consequently, there is no impossibility in the nature of the thing, that one kind of metal should be transmuted into another.

Having first supposed this, I farther considered, that a certain menstruum, which, according to the doctrine of vulgar chymists, is a worthless liquor, must, according to my apprehension, have an extraordinary virtue with regard to gold; I mean, not only to dissolve, and, otherwise, alter it, but to injure the very texture of that metal. To this purpose, I made a menstruum to dissolve gold, by pouring on the rectified oil of butter of antimony, as much strong spirit of nitre, as would serve to precipitate out of it all the *Bezoarticum minerale*; and then with a smart fire, distilling off all the liquor, which would come over, and cohobating it upon the antimonial powder: for tho' several chymists throw this liquor away, upon presumption, that the ingredients have, in the ebullition destroy'd each other; yet experience hath made me prize it, and give it the name of *Menstruum peracutum*. Having provided a sufficient stock of this liquor, we took a quantity of the best gold, and melted it with three or four times its weight of copper; this mixture we put into good *Aqua fortis*, or spirit of nitre, that, all the copper being dissolved, the gold might be left pure, and finely powdered, at the bottom. After the metal had, in this best manner, been most highly refined, and brought to its usual lustre by heat, we put to it a large proportion of the *Menstruum peracutum*, wherein it dissolves slowly and quietly; and there remained at the bottom of the glass, a considerable quantity of white powder, that the menstruum would not touch, and which we found, also, as indissoluble in *Aqua regia*. The solution of gold being abstracted, and the gold again reduced into a body, yielded, upon a second solution, more of the white powder, but not so much as at the first. Now having some little quantity of this powder, it was easy, with borax,

borax, or some other convenient flux, to melt it down into a metal, which metal we found to be white like silver, and yielding to the hammer: and some of it being dissolved in *Aqua fortis*, or spirit of nitre, confirm'd us, by the odious bitterness it produced, in our expectation to find it true silver. I was farther confirm'd herein, first, by finding, that with some other menstrua, and even with good *Aqua regis* itself, I could obtain, from the very best gold, dissolved in them, some little quantity of such a white powder; but in so very small a proportion to the dissolved gold, that I never had enough of it, at once, to make me think it worth prosecuting such trials. Secondly, by the experience of a judicious person, who had, by dissolving gold in a certain kind of *Aqua regis*, and, after, by bringing it into a body, redissolving it, and repeating this operation very often, reduced a very great part of an ounce of gold into such a white powder. And a third confirmation, I had from some trials purposely made, wherein this *Menstruum peracutum* had greater effects upon gold, than by most men, and even critics in chymistry, have been thought feasible. Hence, there appears no greater cause to doubt, that the above-mentioned silver was really obtained out of the pure gold, than this, that men have hitherto so often in vain attempted to make a real transmutation of metals, and to destroy the most fixed and compact body of gold; the one of which is looked upon as an impracticable thing, and the other as an indestructible metal.

If, therefore, we have not imposed upon ourselves, this experiment, which yet we once repeated, may afford some reflexions of moment. And, first, it seems from hence probable, that however irrationally the chymists talk of a *Tinctura auri* and *Anima auri*, yet some such thing may, with due restriction, be admitted; for some of the more noble corpuscles, which qualify gold to look yellow, to resist *Aqua fortis*, and to exhibit those other curious phenomena, which discriminate it from silver, may, either have their texture destroy'd by a very piercing menstruum; or, by a greater congruity with its corpuscles, than with those of the remaining part of the gold, may stick closer to the former; and, by their means, be extricated, and drawn away from the latter. Thus, when the corpuscles of sulphur and mercury, by a strict coalition, associate themselves into the body we call vermilion; tho' these will rise together in subliming vessels, and act, in many cases, as one physical body; yet, when exquisitely mixed with a due proportion of salt of tartar, the parts of the alkali associate themselves more strictly with those of the sulphur, than these were before associated with those of the mercury; whence there will be obtained out of a cinnabar, intensely red, a real mercury, in appearance, like to fluid silver. So that, as our menstruum may, probably, have a particular operation upon some tinging parts of the gold, it is not impossible, the yellowness of that metal should proceed, not from any particular corpuscles of that colour, but from the texture; as in the cinnabar, which was highly red, tho' the mercury it consisted of, was silver-coloured, and the sulphur but a pale yellow: and, consequently, the whiteness, and other changes, produced in the new metal we obtained, may be attributed, not to the extraction of any tinging particles, but to a change of texture, whereon

PHYSICS. whereon depended the colour, as well as other properties of the gold. And this suggestion is supported, by what hath been, often, assured me, that a person in the *Netherlands*, grew rich, by extracting a blue tincture out of copper, with a peculiar clear menstruum, of a weak taste, after it had been first dissolved in common *Aqua fortis*; so as to leave the body white, and reducible by fusion into a metal of the same colour: which I the less wonder at, because *Agricola*, mentions the making of a white and malleable copper, in large quantities, upon his own knowledge; and I have myself, with pleasure, made the experiment. Secondly, tho' gold is, generally, supposed too fixed and permanent a body, to be changeable by art; yet it is not absolutely indestructible thereby: since, being acknowledged an homogeneous metal, a part of it was, by our experiment, really changed into a body, which was either true silver, or, at least, a new kind of metal, very different from gold. And, since it is generally confessed, that no body has its form more strictly united to its matter, than gold; and since this white powder was produced out of it, only by a corrosive liquor, without violence of fire; it seems highly probable, that there is not any body, of so constant and durable a nature, but that its texture, and, consequently, its nature may be really destroy'd by some powerful agent, in due manner applied to it. And, lastly, it seems deducible, from the whole, that there may be a real transmutation of one metal into another, made by factitious agents, in a short time, and after a mechanical manner. I speak not here of projection, whereby one part of an aurific powder, is said to turn many hundred or thousand parts of an ignobler metal into silver or gold; because, tho' projection includes transmutation, yet transmutation is not the same with projection, but far easier. It suffices that we are here taught, that amongst inanimate bodies, the most noble and constant sort of forms, are but peculiar contrivances of the matter, and may, by locally moving the parts, and changing their sizes, shape, or texture, be generated and destroy'd; since we see, that in the same parcel of metalline matter, which a little before was true and pure gold; by having some few of its parts withdrawn, and the rest transposed, or otherwise altered in structure, or by both, the form of gold, or that peculiar modification which made it yellow, indissoluble in *Aqua fortis*, &c. is abolished; whilst, from the new texture of the same matter, there arises that new form, or convention of accidents, from which we call a metal silver. And since ours was not only dissoluble in *Aqua fortis*, but manifested that excessively bitter taste, which is peculiar to silver; there is no necessity for a distinct agent, or a particular action of a substantial form, to produce, in a natural body, the most peculiar and discriminating properties. For it was the same menstruum, devoid of bitterness, that by destroying the texture of gold, changed it into another, upon whose account it acquired, at once, whiteness of colour, dissolubleness in *Aqua fortis*, an aptness to compose a bitter body with it, and many other new qualities. It may, indeed, be readily objected, that it is no very thrifty transmutation, to degrade gold to the condition of silver: but a transmutation is never the less real, for not being gainful; and it is no small matter to remove the bounds,

bounds, which nature seems very industriously to have set to the alterations of bodies; especially amongst those durable, and, almost, immortal kinds, in whose constancy to their first forms, she appears to have affected to shew herself invincible by art.

But farther to demonstrate the efficacy of our *Menstruum peracutum*, we took the finest gold that could be procured, and having either granulated, or brought it into plates, dissolved it in a moderate heat, with a sufficient quantity of the menstruum; and having carefully decanted the solution into a retort, we very gently, in a sand-furnace, distill'd off the liquor: and if we had a mind to elevate more gold, we either poured back upon the remaining substance the same menstruum, or dissolved it again with fresh. The liquor being abstracted, we urged the remaining matter by degrees of fire; and in no stronger an one, than may easily be given in a sand-furnace, a considerable quantity of the gold would be elevated to the upper part of the retort; and either fall down, in a golden-coloured liquor, into the receiver, or fasten itself to the top and neck, in the form of a yellow and reddish sublimate: and sometimes we had the neck of the retort enriched with numerous large thin red crystals, very like rubies, and glorious to behold, which would run in the air *per deliquium*. Nor can I see any cause to doubt, that, by the re-affusions of fresh menstruum upon the dry calx of gold, which remains behind, the whole body of the metal may be easily made to pass through the retort; tho' I forbore to prosecute the experiment so far.

It may here be necessary to give a caution; that tho' chymists think it a sufficient proof of a true tincture, that the colour of the concrete will not be separated in distillation, but the extracted liquor pass over tinged into the receiver; yet this supposition may, in some cases, deceive them. And, farther, whereas the particles of solid and consistent bodies, are not, always, unfit to help to compose fluids, I shall venture to add, that even a liquor, made by distillation, may, in part, consist of corpuscles of the most compact and ponderous bodies in the world. To manifest this, as well as, that some bodies are of so durable a texture, that their minute parts will retain their own nature, notwithstanding variety of disguizes, which may impose even upon chymists themselves; I dropped into the yellow liquor, afforded me by the elevated gold, a quantity of clean running mercury, which was immediately tinged with a gold-coloured film; and shaking it about, till the menstruum would gild no more, I decanted the clarified liquor; and mixing the remaining amalgam of gold and mercury with several times its weight of borax, I by fusion easily recover'd the scatter'd particles of the metal into one little mass of yellow gold. And whensoever mention is made of a volatile gold, as it is said to be in some minerals, it may be admitted with this explanation, that in our experiment, after abstraction of the menstruum, the remaining body being true gold, and, consequently, in its own nature fixed; yet it is so strictly associated with some volatile saline particles, that these being pressed by the fire, carry up along with them the corpuscles of the gold, which may be reduced into a mass by the admixture of borax, or some other

PHYSICS.

other-body, fitted to divorce the corpuscles of the metal from those that would elevate them, and to unite them into grains, too big and ponderous to be sublimed: thus, in some mineral bodies, there may be numberless corpuscles of gold, so minute, and so blended with the unfixed particles, that they will be carried up together with them by that vehement heat usually employ'd to bring ores, and metalline masses, to fusion. Yet it is not impossible, that these corpuscles of gold, which, in ordinary fusions, fly away, may be retained, and recovered by some such proper addition, as may either work upon, and mortify the other parts of the mass, without doing so to the gold; or by associating with the volatile, and ignobler minerals, prevent their carrying away the gold with them, as they otherwise might; or, by its fixedness, and similitude of nature, make the dispersed gold embody with it. Thus, I remember, that some good gold, having, for a certain trial, been cupel'd with a great deal of lead, instead of being advanced in colour, as in goodness, was grown manifestly paler than before; whence I conjectured, that so great a proportion of lead, might contain several particles of volatile silver; which, meeting with the fixed body of the gold, by incorporating therewith, might be detained: and I was confirmed herein, by finding, upon enquiry, that the gold, instead of losing its weight, had considerably increased it.

It is varied by
mechanical alter-
ations in bodies.

8. We took an ounce of refined silver, and, having dissolv'd it in *Aqua fortis*, suffered it to shoot into crystals; which, being dried, we found to exceed the weight of the silver, by several drams, gain'd by the concoction of the acid salts, that had dissolved, and were united to the metal. These crystals we put into a retort, and distill'd them in sand, with, almost, as great a heat as we could give in an iron-furnace: but there came over only a very little fourish phlegm, of an ill scent; wherefore, the same retort being suffered to cool, and being then coated, it was removed to another furnace, capable of giving a far greater degree of heat; and, in this, the distillation was pursued with several degrees of fire, till the retort became red-hot, and long continued so: but tho, even by this operation, there was very little driven over; yet it sufficiently manifested, that a body extremely bitter, might afford numerous parts not at all bitter, but eminently sour. For our receiver being taken off, even when cold, the contained spirit smoked like rectified *Aqua fortis*; and not only smelt and tasted like it, but being poured upon filings of crude copper, immediately corroded them; and, in a trice, produced a bluish colour, like what that metal gives in good *Aqua fortis*. Afterwards, we made a solution with minium and *Aqua fortis*, which being filtered, and evaporated, left a *Saccharum Saturni*, much like the common, made with spirit of vinegar: then taking this sweet-vitriol of lead, we endeavoured, in a sand-furnace, to drive it over; but finding that degree of heat insufficient, we caused the retort to be coated, and transferred it to the other furnace; where, being urged with a naked fire, it afforded somewhat more spirit than the silver had done. This spirit smoked in the cold receiver, as the other; and, like it, smelt of *Aqua fortis*, and was so far from retaining any of the sweetness of the concrete which yielded

yielded it, that it was offensively acid; and being poured upon minium, work'd upon it with noise and bubbles, and quickly afforded a sweet liquor, from whence might have been obtained a true sugar of lead. It is remarkable, that the concrete, which appeared white before distillation, remained, for the most part, behind in the retort, in the form of a black *Caput mortuum*, which was neither sweet nor sour at all, but seemed rather insipid, and was, indeed, but a calx of lead.

In this experiment, it may be observed, that tho' silver be a body so fixed in the fire, as to endure the cupel itself; and, tho' in the dry'd crystals of silver, the salt, that adheres to the metal, increases its weight but about a third or fourth part; yet this small proportion of saline corpuscles was able to carry up so much of that fixed body, that the inside of the retort was, to a great height, cover'd over with the metalline corpuscles. But the phenomenon which I chiefly take notice of, is, that not only *Aqua fortis*, being con-coagulated with different bodies, may produce very different concretes; but the same numerical saline corpuscles, which, being associated with those of a metal, had already produced a body, eminent in one taste, may, afterwards, being freed from that body, compose a liquor, remarkable for a very different taste; and after that too, being combined with the particles of another metal, with them, constitute a body of a very eminent taste, directly opposite to both the other; and yet these saline corpuscles, if instead of this second metal, they should be associated with such an one, as that they are driven from, would therewith again exhibit the first taste. To prove all this, we took crystals of refined silver made with *Aqua fortis*, and tho' these crystals are excessive bitter; yet having, by a naked fire, extorted from them what spirit we could, and found it extremely acid, we put one part of it upon a few filings of silver, of which it readily made a solution, more bitter than gall; and the other part of the distill'd liquor we poured upon minium; when, tho', whilst it was an ingredient of the crystals of silver, committed to distillation, it did, with that metal, compose an intolerably bitter substance; yet the same particles, being loosened from that metal, and associated with those of the lead, with them constituted a solution, which, by evaporation, afforded a *Saccharum Saturni*, sweet as sugar. For farther confirmation, we varied the experiment; and having, in a naked fire, distill'd some dry'd *Saccharum Saturni*, made with *Aqua fortis*, the little liquor which came over, in proportion to the body that afforded it, was so strong a spirit of nitre, that for several hours the receiver was filled with red fumes; and tho' the smoking liquor was vastly sharp, yet part of it being poured upon a piece of its own *Caput mortuum* (in which we perceived no taste) at length exhibited some little grains of a saccharine vitriol; but the other part, being put to filings of silver, immediately fell upon them, with noise and smoke, and soon after, con-coagulated with part thereof, into a salt excessively bitter.

9. Having put a considerable quantity of distill'd rain-water into a clean glass-body, and fitted it with a head, and receiver, I suffer'd it to stand in a digestive furnace, till, by the gentle heat thereof, the water was to-
Water transfused into earth.

PHYSICS.

tally abstracted, and the vessel left dry ; when, being taken out of the sand, I found the bottom of the glass wholly covered with a whitish substance, which being scraped off with a knife, appeared to be a fine earth, without any manifest taste. This encouraged me to distil the rain-water again in the same glass-body, in the bottom whereof, when the water was all drawn off, lay more of the like earth, which confirmed my conjecture, that the earthy powder might be a transmutation of some parts of the water into that substance. Herein, also, I was farther encouraged by a physician, who assured me, that he had frequently found such a white earth in rain-water, after distilling the same many times successively ; adding, he found no cause to suspect, that if he had continued to re-distil the same portion of water, it would have yielded him more earth. But the oddness of the experiment still keeping me in suspense, a very ingenious person, who had try'd various experiments upon rain-water, gave me such an account of his proceedings, as left me but little scruple about this transmutation : for, he solemnly affirmed, on experience, that rain-water, even after distillation in very clean glasses, near two hundred times, afforded him this white earth, and that more conspicuously in the latter distillation, than in the former. And in comparing this powder with what I made myself, I found an agreement between them. And, (1.) Being placed in an excellent microscope, and exposed so that the sun-beams might fall thereon, it appeared a white meal, or an heap of corpuscles exceeding small ; and their extreme smallness was more sensibly discerned by adding some grains of sand thereto, which made a mixture that looked like that of pebble-stones, and the finest flower. For our earth, even in the microscope, appeared to consist of as small particles, as the finest hair-powder, to the naked eye. Nor could we discern this dust to be transparent, tho' when the sun shone thereon, it appeared to have some particles a little glittering. (2.) I found, that our powder being cast into water, would, for a time, somewhat whiten it ; but when it was once settled at the bottom, it continued there undissolved, for some days, as earth would have done. (3.) Having weighed a quantity, and put it into a new clean crucible, with another inverted over it, I placed it among quick coals, and there kept the crucible red-hot for some time, causing the fire, afterwards, to be raised ; but taking out the powder, I neither found it melted, clotted, nor much wasted, besides what stuck to the sides of the crucible, and to a little clay, wherewith I had luted on the cover. And when I, afterwards, kept this powder in an open crucible amongst glowing coals, I could not perceive it at all to smoke ; and having put a little upon a quick coal, it remained fixed, which some bodies will not, that yet endure the fire in a red-hot crucible. (4.) I found this powder to be much heavier in specie than water : for employing a nice pair of scales, it balanced somewhat more than twice its bulk of common water. I, farther, took some wood-ashes, which I had caused to be boiled three or four times in a plentiful proportion of water, to free them from salt ; and having put them, very dry, into common water, found them but little heavier than our powder ; surpassing in weight, water of the same bulk but twice, and a little more than a sixth part. We may add, that glass, which is a very compact body,

body, is but little, if at all, more than twice and a half as heavy as water of equal bulk ; so that the gravity of this powder, being added to its fixedness, and other qualities, justly entitles it to the distinction of earth. My learned friend, before-mentioned, hath procured of it near three quarters of an ounce from one ounce of water.

These several relations, in a very singular manner support the corpuscular principles. For, if the elements themselves are transmutable, and those simple and primitive bodies, which nature is presumed to have intended stable and permanent ingredients of the bodies she compounds, may by art be destroyed, and re-produced ; why may not the changes, which happen in other bodies, proceed from the local motion of the minute or insensible parts of matter, and the changes of texture consequent thereto ? Some atomists would here be determining, by what particular ways this strange transmutation of water into earth may be performed ; and, particularly, tell how the continual, but slowly agitated parts of water, by their innumerable occurrences, may, by degrees, rub themselves into such surfaces, as either to stick very close to one another by immediate contact, or entangle themselves into clusters of coherent particles, too heavy to be supported by the water. But tho' many things in favour of such conjectures, may hence be urged ; yet the full disquisition of so difficult a subject, is too long and intricate to be proper for this place. And, therefore, we will, for a while, suppose this transmutation real ; and consider, whether it doth not much discredit some of the chief doctrines of the chymists, and a fundamental one of *Helmont*. For if the purest water may be turned into earth, it will be easy to make it probable, that the other ingredients of mixed bodies, which the chymists call their hypostatical principles, are capable of being transmuted into one another. Besides, if out of the simplest water, a moderate fire can produce a large proportion of earth, which was not formerly pre-existent in it ; how shall we be sure in all the analyses, which the fire makes of mixed bodies, the substances thereby exhibited, are obtained by separation only, without any transmutation ? *Helmont*, we know, makes water to be the material principle of all bodies. But as his grand argument is grounded on his alkalest, which, as he affirms, by being digested with, and distilled from other tangible bodies, reduces them all, at last, into a liquor no way different from rain-water ; tho' we should grant the fact, yet the experiment of our powder will warrant us to question the conclusion. For if all mixed bodies be therefore, materially from water, because they are, by the operation of a fire and a menstruum, after having passed through several previous changes, reduced, at length, into insipid water ; by the same way of arguing, I might say, that all those bodies are materially but disguised earth, since water itself may be turned into earth.

But to leave these reflexions, I would not have it thought strange, that whilst I insist upon the many particulars, which seem to evince the change of water into earth, I should intimate a diffidence about it. For I must confess, that having unluckily lost a whole paper of the powder I had myself made ; and having, unexpectedly, been obliged to remove from my furnaces,

PHYSICS.

before I had gone thro' half the trials, I judged requisite in so nice a case ; I have not yet laid aside all my scruples. For, (1.) I would gladly know, whether the untransmuted rain-water, by the deposition of so much terrestrial matter, were grown lighter in specie than before, or sharp in taste ; and I would, also, be satisfied, whether insipid liquors may not work as menstrua upon stones, or earthy bodies : not to question, whether the particles of rain-water may not, by their mutual attrition, or some other action upon one another, be reduced into shapes and sizes fit to compose such a menstruum, as the liquor was not before ; as in several plants, which seem to be nourished only with water, the sap is endowed with a sharp taste, great penetrancy and activity of parts. (2.) It were also fit to know, whether the glass-body, wherein all the distillations are made, loses of its weight, any thing near so much as the obtained powder amounts to, over and above the decrease of weight, which may be imputed to the action of the heat upon the substance of the glass, in case it appear by another glass, kept empty in an equal heat, and for the same time, that the glass loses by such operations any thing considerable. And it were, also, not impertinent to try, whether the gravity of the obtained powder be the same in specie with that of the glass, wherein the distillations were made. (3.) I could wish, likewise, that it were more demonstrably shewn, what is, on all hands, taken for granted, that distill'd rain-water is a perfectly homogeneous body : for if it be not, many suspicions might be suggested about its transmutation into earth ; and if it is, it will be very difficult to conceive, how a perfectly and exquisitely homogeneous body should, without any addition, or any feminal or plastic principle, be brought to afford a large quantity of a matter of much greater specific gravity than itself ; since we see, that no aggregate, we can make, of bodies, equiponderant in specie with water, by virtue of their convention, grows specifically heavier than it. (4.) Having had the curiosity to try, whether corrosive liquors would operate upon our white powder, I found, that not only good oil of vitriol would corrode it, but strong and dephlegmed spirit of salt readily work'd upon part of it ; and that, without the assistance of heat, tho' not without hissing, and exciting numerous bubbles : yet, when I suffered this mixture to settle, a very great proportion of the powder remained in the lower part of the liquor, as if that had rather fretted, than dissolved it. Nor must I omit, that sometimes I have excited such an ebullition, by pouring the same liquors upon the earthy part of wood-ashes, several times washed in boiling water : to which might be added, that sometimes, also, I have thought this powder gritty between my teeth. But whether it be truly earth or not, the alteration is so great, and effected in so simple a way, that it cannot but afford us a considerable instance, of what the varied texture of the minute parts may perform in a matter confessedly similar. And, if frequently distill'd rain-water should not be allowed homogeneous, our experiment will excellently shew, how little we are bound to believe what the chymists, and others, tells us, when they pretend, manifestly, to exhibit homogeneous principles, and elementary bodies ; and how difficult it is to be

be certain, when a body is absolutely irresoluble into specifically different substances; and, consequently, what is the determinate number of the perfectly simple ingredients of bodies. I will not now mention my attempts to transmute pure alkalizate salts into earth, because I do not yet know, whether the trials will answer my hopes: but upon this subject, I could add something about the changes, which may be wrought upon highly rectified spirit of wine, which would, perchance, make other things of the like kind thought more feasible. For, whereas it is a known thing, that this spirituous liquor being kindled, will, for ought appears, be totally turned into flame; yet I have, without any addition, obtained from such spirit of wine, a considerable quantity of incombustible phlegm. And, by another way, some persons, working by my directions, reduced considerable quantities of high-rectified spirit of wine into a liquor, which was, for the most part phlegm; from which change, it seems deducible, that the same portion of matter, which, by being kindled, would be turned all into fire, may, by another way of management, be turned into water; and this, without the addition of any thing, and without being wrought upon by any visible body, but one so extremely dry, as duly prepared salt of tartar; and that itself is not indispensably necessary, because I, by another way, obtained this phlegm, without employing the salt, or any other visible body whatever.

10. There is one experiment more, with which I design to conclude. Take of good oil of vitriol, and spirit of wine, that will burn all away, equal parts in weight; put them together gradually, and having placed the mixture in a bolt-head or glass-egg, with a long neck, and carefully stopped it with a cork and hard wax, set the vessel, in a moderate heat, to digest for a competent time; then pour out the mixture into a tall glass cucurbite, to which carefully lute on a head and a receiver; and, with a very gentle fire, abstract the spirit of wine, which will first ascend: and when the drops begin to come over sourish, shift the receiver, and continue the distillation with great care, that the matter boil not over; and when about half the acid liquor is come over, change the receiver once more, and continue the distillation; increasing the fire towards the latter end, till you have brought over all you can: and what remains in the bottom of the cucurbite must be put into a glass, well stopped to keep it from the air.

Phenomena from the distillation of oil of vitriol with spirit of wine.

(1.) To the production of most, if not all the phenomena of this experiment, it is not absolutely necessary, that a long digestion be premised, tho' the experiment will succeed the better for it. (2.) I have, sometimes, made use of oil of sulphur *per Campanam*, instead of oil of vitriol; and tho' it succeeded in several particulars, yet I afterwards chose to employ oil of vitriol, both because it, in some points, better answer'd; and, because I would not give occasion to suspect, that the odours, hereafter to be mentioned, as phenomena of our experiment, were owing to the common sulphur, and no way proceeded from the acid salt, wherewith that oil abounds. (3.) I, likewise, digested oil of vitriol with *Spanish* wine, instead of spirit of wine, and, by this means, obtained an odd spirit, and residue, with some other phenomena, which, in regard wine is a liquor of a less simple nature

than

PHYSICS.

than its spirit, are less fit for my present purpose. (4.) Great care must be had in regulating the fire, when once a considerable part of the acid spirit, mentioned in the process, is come over. For, if the fire be not increased, the rest will scarce ascend: and if it be increased a little too much, the matter will be apt to swell in the cucurbite, and run over into the receiver.

Now the oil of vitriol, and spirit of wine, being both of them distilled liquors, drawn from simple and familiar substances, and, consequently, volatile; one would expect, that they should be brought over united, as I have tried, that the spirit of wine, with that of nitre, or of common salt, may be; and as the spirits of different vegetables are; or, at least, that the distillation should not much alter them from what it found them, after they had been well mixed together; yet they exhibited several considerable and surprizing phenomena. For, first, whereas spirit of wine has no great scent, nor a good one, and moderately dephlegmed oil of vitriol is inodorous; the spirit, which first comes over from their mixture, hath a scent not only very different from spirit of wine, but from all things else, that ever I smelt. And as this new odour seems very fragrant, I have sometimes had it so exceeding subtle, that in spite of the care which was taken to lute the glasses exactly, it would perfume the neighbouring parts of the laboratory, and not, afterwards, be kept in by a close cork, covered with two or three several bladders, but would smell strongly at some distance from the vial that contain'd it. But, 2. to shew how much the odours of bodies depend upon their texture; after this volatile spirit is come over, and has been followed by an acid one, it will usually, towards the latter end of the distillation, be succeeded by a liquor, that smells strongly of brimstone. 3. There is produced in this operation, a liquor, that will not mix either with the mentioned fragrant, or with the fetid spirit, but is very different from both; and so very pleasant, subtle, and aromatic, that it recedes as well from spirit of wine, as oil of vitriol. 4. When the distillation is carried on far enough, you will find at the bottom, that the two spirits above-mentioned, (for oil of vitriol is rather a saline spirit, than an oil) have produced a black substance, almost like pitch or jet. 5. And this substance, tho' produced by two bodies, which were not only fluid, but distill'd, will be both consistent and brittle. 6. Tho' spirit of wine be reputed the most inflammable, and oil of vitriol the most corrosive liquor known; yet I could not find, that this black substance would easily, if at all, be brought to flame or burn; nor that it had any discernible taste, tho' both the liquors, from whose mixture it was obtained, are exceeding strong and pungent. 7. Tho' both these liquors will mix with common water, I observed, that this pitchy mass would not dissolve therein for very many hours. And, lastly, tho' the oil of vitriol, and the spirit of wine, were both of them distill'd liquors, and one of them exceeding volatile and fugitive; yet the black mass produced by them, was so far fixed, that I could not make it rise by a considerably strong and lasting fire, that would have raised a much more sluggish body, than the heaviest of those, which concurred to produce it.

Now,

Now, in these experiments, it cannot well be pretended, that any substantial forms are the causes of the effects recited: for, besides, that in the bodies employ'd in most of the cases, the seminal virtues, if they had any before, may be supposed to have been destroy'd by the fire; they were such, as those I argue with, would account factitious, being artificially produced by chymical operations. And it is not more manifest, that in the production of these effects, there happens a local motion, and change of texture, by the operations, than it is precarious, that they are the effects of such things, as the schools fancy substantial forms to be. And, since it is in these experiments, by the addition of some new particles of matter, or the recess or expulsion of some pre-existent ones; or, which is the most frequent way, by the transposition of the minute parts; yet, without excluding the other two; that I have been able to produce, by art, a number of such considerable changes of qualities, as are not ordinarily presented us by nature, where she is presumed to work by the help of substantial forms; it is, surely, probable, that the same universal and fertile principles, motion, bulk, shape, and texture, of the minute parts of matter, may, under the conduct of nature, suffice, likewise, to produce those other qualities of natural bodies, of which we have given no particular instances.

S E C T. VIII.

THE term quality, is very ambiguous, and has been applied to some things, which ought rather to have been look'd upon as states of matter, or complexions of particular qualities, as animal, health, beauty, &c. There are, also, other attributes, as size, shape, motion, and rest, usually reckon'd among qualities, which may more conveniently be esteem'd the primary modes of the parts of matter; since from these simple attributes, all the qualities are derived. Remarks upon particular qualities.

One of the more received divisions of physical qualities, is into manifest and occult. We distribute the former into first, second, and third; to the two last of which, we may refer several qualities not treated of by school-writers of physical systems: and these, for distinction sake, might, some of them, be styl'd the chymical qualities of things; because *Aristotle* and the school-men, being unacquainted with them, they have been principally introduced by means of chymical operations and experiments: such are fumigation, amalgamation, cupellation, volatilization, precipitation, &c. by which operations, among other means, corporeal things come to appear volatile or fixed, soluble or insoluble in some menstrua, amalgamable or unamalgamable, &c. which as well deserve the name of qualities, as several other attributes, to which it is allow'd. And to these chymical qualities, some others might be added, which, because of the use that physicians principally make of them, may be call'd medical; whereby some substances receiv'd into the human body, are resolving, dissolving, suppurating, absterfing, &c. For tho' some faculties of medicines, as those of heating, cooling, drying, attenuating, purging, &c. may be conveniently referr'd to the first, se-

PHYSICS.

second, or third qualities, mentioned by naturalists, whilst others are reckon'd occult; and tho' these medical qualities are treated of by physicians; yet as several of them ought not to be referr'd to the qualities whereto they are often ascribed; so the handling of them, may be look'd upon as a desideratum, and well deserves a distinct place, in natural philosophy.

But before I proceed, I think proper to solve three grand scruples, which may possibly arise in our doctrine of qualities. The first of these, proceeds from the opinion of vulgar and *Aristotelian* philosophers, that diversity of qualities must needs flow from substantial forms; either, because it is part of their nature to be the principles of properties, and peculiar operations in the bodies they inform; or else, because several of them, are such as no mixture of the elements is capable of producing.

We have, already, in examining substantial forms, shewn the first of these two suppositions unworthy to be admitted. It, therefore, only remains, that we examine, also, the second supposition; to which, *Semertus* adds, that, as no bare mixture of the elements, so no general *forma mixtionis* is sufficient to account for several qualities, which he enumerates.

But as this difficulty takes it for granted, that there are four elements, from whose various mixtures, all other sublunary bodies arise; whence, they are only solicitous to prove, that particular qualities cannot flow from their mixture; I am not concern'd in their whole discourse, because I admit not the hypothesis of the four elements: yet I may observe from hence, that by the confession of such modern *Peripatetics*, as urge this argument, those, and other *Aristotelians*, were mistaken, who ascrib'd to the mixtures of the elements, effects, for which these maintain them to be insufficient. I shall, however, consider the difficulty itself, not only as it may be propos'd by *Peripatetics*, but by chymists; who, tho' some of them do not allow of the four elements, yet agree, with the schools, that there is a determinate number of ingredients of compounded bodies, from whose mixture and proportion many qualities must be deriv'd; those that cannot, being resolv'd to flow from a higher principle, whether it be a substantial form, or something for which chymists have several names, tho', I doubt, no settled idea.

But, first, I readily acknowledge, that in some respects, and in some cases, this grand supposition may be well-grounded; but then, I look upon it, rather as a part of the corpuscular doctrine, than an objection against it: for when there happens a strict connexion betwixt the modification of matter, which is requisite to exhibit one phenomenon, and that from which another will necessarily follow; we teach, that he, who, by a change of texture, gives a portion of matter the former modification, likewise qualifies it, by the same change, to exhibit the phenomenon agreeable thereto; tho' one would not, perhaps, suspect them to have any such dependance upon one another. Thus, for instance, strong spirit of distill'd vinegar, by virtue of its being an acid spirit, hath the faculty to turn syrup of violets red; but, if by making with this spirit, a strong solution of coral, you destroy the acidity of the spirit of vinegar; this liquor, as it has quite another taste, so it will have another operation, than formerly, upon the syrup of violets.

For

For upon a trial, I purposely made to illustrate this matter, I found, that the solution, just mention'd, and some others, made with spirit of vinegar, would presently, like an alkaline or urinous salt, turn syrup of violets from its native blue, to a lovely green. And prosecuting the experiment, it appear'd, that spirit of salt, dephlegmed by a fit concrete, tho' the solution were vehement strong, had yet the same effect on syrup of violets. Now, things may acquire, by mixture, very different qualities from those of any of the ingredients. Thus sugar of lead is extremely sweet, tho' the minium and the spirit of vinegar, of which it is made, be, the one insipid, and the other sour. And, tho' neither *Aqua regis*, nor crude copper, have any thing in them of blue; yet the solution of this metal in that liquor is of a deep blue: and, sometimes I have had the solution of crude mercury in good *Aqua fortis*, of a rich green; tho' it would not long continue. So that they are much mistaken who imagine, either that no manifest qualities can be produced by mixture, except those that reside in the elements, or result immediately from the combinations of the four first qualities. For it is manifest, that nature and art must continually make mixtures of bodies, both already compounded; as when ashes and sand compose the common coarse glass; or when nature combines sulphur with unripe vitriol, and, perhaps, other substances, in a marcasite; and, also, of bodies already re-compounded; as native vitriol is made in the bowels of the earth of an aqueous liquor impregnated with an acid salt, and of a cupreous or ferruginous mineral, strictly united both to a combustible sulphureous substance, and to another body of a more fixed and terrestrial nature. And thus artificers may easily produce fine new colours, by skilfully mixing in the flame, two pieces of amel of colours more simple than that which results from their colligation. And this way of combining bodies, not simple or elementary, will be acknowledged more extensive in the production of various qualities, and phenomena of nature, from considering how much the variation of the proportion of the ingredients in a mixed body, may alter the qualities and operations of it; and that this proportion may be varied, almost in infinitum.

I next observe, that it is an ill-grounded hypothesis to suppose, that new qualities cannot be introduced into a mixed body, or those that it had before be destroy'd, unless by adding or taking away a sensible portion of some one or more of the *Aristotelian* elements, or chymical principles. For there may be many changes, as to quality, produced in a body, without visibly adding or taking away any ingredient, barely by altering the texture, or the motion of the minute parts it consists of. When water, hermetically seal'd up in a glass, is, by the cold, turn'd into ice, and thereby both loseth its former fluidity and transparency, and acquires firmness, brittleness, and opacity, which qualities leave it again upon a thaw; I demand, what element, or hypostatical principle can be shewn to get into or out of this seal'd glass, and by its intrusion and recess, produce these alterations in the included body? So in that fixed metal silver, what sensible accession or decrease can be proved to be made, as to ingredients, when, by bare hammering,

mering, it acquires a brittleness, which, by heating in the fire, wherein it sensibly loses nothing, it may presently be made to exchange for its former malleableness: and the same experiment, also, shews, that the invisible agitation of the parts may alone suffice to give a body, at least for a while, new qualities; since a thick piece of silver briskly hammer'd, will quickly acquire a considerable degree of heat, whereby it will be enabled to melt some bodies, to dry others, and to exhibit various phenomena, that it could not produce when cold. I might add, that spirit of nitre, tho' when included in a well-stopp'd vial, in the form of a liquor, it appears transparent, and without redness, will yet fill the upper part of the vial with red fumes, if the warm sun-beams, or any fit heat, put the nitrous spirits into a brisker motion than they had whilst in the form of a liquor. I might, also, demand what new element, or principle, is added to a needle, when the bare approach of a vigorous load-stone, endows it with those admirable qualities of respecting the poles, and drawing other needles to it; and what ingredient the steel loses, when by a contrary motion of the load-stone, it is, in a minute, deprived of its magnetism.

In the third place, it must be remember'd, as we formerly observ'd, that when we consider how numerous and various phenomena may be exhibited by mixed bodies, we are not precisely to look upon them as portions of matter of a determinate nature or texture, but as they are parts of our system, and, consequently, placed among other bodies. For being hereby fitted to receive impressions from some of those bodies, and to make impressions upon others, they will, upon this account, be render'd capable of producing, either as principal or auxiliary causes, a much greater number and variety of phenomena, than they could, if each of them were placed in a medium, that no way contributed to, or hinder'd its operations.

In the last place, I assert, that the four *Peripatetic* elements, and the three chymical principles, being unable to give a tolerable account of the phenomena of nature, we must seek for some more universal principles; and, that those of the corpuscular philosophy, have a great advantage in being far more fertile and comprehensive than they. Such phenomena, as the constant and determinate shape and figure of the mountains in the moon; the strange generation and perishing of the spots of the sun, &c. cannot be ascribed to the four elements, or their mixtures; nor to those of the three chymical principles, which are allow'd to be confin'd to the sublunary region. And there are very many phenomena in nature, several whereof, neither the *Peripatetic*, nor the chymical doctrine about the elements, or the ingredients of bodies, will enable us to solve; as the eclipses of the sun, the moon, and the satellites of *Jupiter*; the proportion of the acceleration of descent observable in heavy bodies; the ebbing and flowing of the sea; with a great number of magnetical, musical, statical, dioptrical, catoptrical, and other sorts of phenomena.

Having thus shewn, that the vulgar doctrine, about the ingredients of bodies, falls very short of solving several kinds of nature's phenomena, it will follow, in general, that it is fit to look out for some more pregnant and uni-

universal principles; and that in particular those of the corpuscular hypothesis are preferable to the vulgar, will appear hereafter. And, indeed, it were strange, if the consideration of the various motions and textures of bodies, should not serve to account for far more appearances, than the bare knowledge of the number of their quiescent ingredients: for as local motion is that which enables natural bodies to act upon one another; so the textures of bodies are the principal things, that both modify the motion of agents, and diversify their effects, according to the various natures of the patient.

I come now to consider the second, and, indeed, the greatest difficulty objected against our doctrine of the origin of qualities. 'Tis incredible, some will say, that so great a variety of qualities, as we actually find in natural bodies, should spring from principles so few in number as two; and those so simple as matter and local motion; whereof the latter is but one of the six kinds of motion reckon'd up by *Aristotle* and his followers, who call it lation; and the former being all of one uniform nature, is, according to us, diversify'd only by the effects of local motion. To solve this difficulty, I shall shew, first, that the other universal affections of matter, are manifestly deducible from local motion; and next, that these principles being variously associated, are so fruitful, that a vast number of qualities, and other phenomena of nature, may result from them.

Now, supposing, what is evident, (1.) that the local motion belonging to some parts of the universal matter, does not all tend the same way, but has various determinations in the several parts of this matter; it will follow, that by local motion thus circumstanced, matter must be divided into distinct parts, each of which being finite, must necessarily have, (2.) some bulk or size; and, (3.) some determinate shape or other.

And since all the parts of universal matter are not always in motion, some of them being arrested by their mutual implication, or, having communicated all that they had to other bodies; the consequence is, that some of the portions of the common matter will be, (4.) in a state of rest. And these are the most primary and simple affections of matter.

But, because there are some others that flow naturally from these; and are, tho' not altogether universal, yet very general and pregnant; I shall subjoin the most fertile principles of the qualities of bodies, and other phenomena of nature.

Farther then, not only the greater fragments of matter, but the less, which we, therefore, call corpuscles, or particles, have certain local respects to other bodies, and to those situations, which we denominate from the horizon; so that each of these minute fragments may have, (5.) a particular posture or position, as erect, inclining, &c. and, with regard to us who behold them, (6.) a certain order, upon account whereof we say, one is before or behind another: and, (7.) many of these fragments being associated into one mass, have a certain manner of existing together, which we call texture, or by a more comprehensive word, modification. (8.) And because there are very few bodies, whose constituent

PHYSICS. parts can, by reason of the irregularity, or difference of their figures, and for other reasons, touch one another every where so exquisitely as to leave no intervals between them; almost all consistent bodies, and those fluid ones, that are made up of grosser parts, will have pores. But (9) very many bodies having particles, which, by their smallness, or their loose adherence to the bigger, or more stable parts of the bodies they belong to, are more easily agitated, and separated from the rest, by heat, and other agents; there will be great numbers of bodies which emit those subtile emanations, that are commonly called *effluvia*. And as those conventions of the simple corpuscles, that are so fitted to adhere to, or be complicated with one another, constitute such durable clusters of particles, as we may call the primary concretions, or elements of things: so (10) these themselves may be mixed with one another, and constitute compound bodies; and even these resulting bodies may, by being mix'd with other compounds, prove the ingredients of re-compounded bodies; and so afford a way, whereby nature varies matter, which we may call mixture, or composition; not that the name is here so proper, as when applied to the primary concretions of corpuscles; but because it belongs to a multitude of associations, and seems to differ from texture; whereto, perhaps, it is reducible, in this, that always in mixtures, but not in textures, there is required a heterogeneity of the component parts. And every distinct portion of matter, whether it be a corpuscle, a primary concretion, or a body of the first, or of any other order of mixt bodies, is to be consider'd, not as if it were placed *in vacuo*, nor as if it had relation only to the neighbouring bodies; but as being placed in the universe, constituted as it is, amongst an innumerable company of other bodies; whereof some are near it, and others very remote; some are great, and some small; some particular, and some general agents; and all of them govern'd as well (11) by the universal fabric of things, as by the laws of motion, established by the author of nature, in the world.

And having thus enumerated eleven very general affections of matter, which, with itself, make up twelve principles of variation in bodies; I may, in behalf of the corpuscular philosophy, apply to the origin of qualities, a comparison of the old atomists, used by *Lucretius*, and others to illustrate the production of an infinite number of bodies, from such simple fragments of matter, as they thought their atoms to be. For, since of the 24 letters of the alphabet, associated several ways, all the words of the several languages of the world may be made; so, say these naturalists, by variously connecting particular numbers of atoms, of particular shapes, sizes, and motions, into masses, an innumerable multitude of different bodies may be formed. Wherefore, if to the four affections of matter, which I call the most primary, and simple, we add the seven other ways, whereby it may be alter'd; we shall have eleven principles so fruitful, that, from their various associations, may result a much vaster multitude of phenomena; and among them of qualities, than one who does not consider the thing attentively would imagine. For, supposing our principles were but as so many letters of the alphabet, that could only be put together in different

num-

numbers, and in various orders; the combinations, and other associations that might be made thereof, is far more numerous, than a man who knows not how to compute them, could easily credit, when told.

But farther, each of these producers of phenomena, admits of a scarce credible variety: for, not to descend so low as insensible corpuscles, many thousands of which may be requisite to constitute a grain of mustard-seed; what an innumerable company of different magnitudes may we conceive, between the bulk of a mite, and that of a mountain, or the body of the sun?

And so, tho' figure be one of the most simple modes of matter; yet it is capable of so great a multitude of differences, that it is of them, and their properties, that *Euclid*, *Apollonius*, *Archimedes*, *Theodosius*, *Clavius*, and later writers, have demonstrated so many propositions. And yet, all the regular figures are nothing to such irregular shapes as may be met with in nature; most of which have no particular appellations, their multitude and variety having kept men even from enumerating them.

I may add, that these varieties of figure and shape, also serve to modify the motion, and other affections of the corpuscles endow'd with them; and of the compound body whereof it makes a part: and that the shape and size of bodies, whether small or great, may exceedingly diversify their nature, and operation, is very manifest, by considering how many different sorts of tools, and instruments, almost each of them fit for many different operations and uses, smiths, and other mechanics, have form'd out of pieces of iron, only by making them of different sizes and shapes.

Thus, likewise motion, which seems so simple a principle, especially in simple bodies, may, even in those, be very much diversify'd: for it may be more or less swift, and that in almost infinite degrees; it may be simple or uncompound'd, uniform or irregular, and the greater celerity may precede or follow; the body may move in a straight line, or in a circle, an ellipsis, hyperbola, parabola, &c. The motion of a body may be also varied, according to the situation, or nature of the matter it hits against, as that is capable of reflecting or refracting it, or both; and this after several manners. It may have an undulating motion, and that with smaller or greater waves; or it may have a rotation about its own axis, or both a progressive motion and a rotation; and the one either equal to the other, or swifter than it, in almost infinite proportions. As to the determination of motion, the body may move directly upwards, or downwards, declining or horizontally, east, west, &c. according to the situation of the impelling body. And besides, these, and other modifications of the motion of a simple corpuscle, or body, whose phenomena, or effects, will be also diversify'd by its bulk and figure; there will happen a new and great variety of phenomena, when several corpuscles, tho' primogeneal, and much more if they be compound'd, move at once, so that the motion is consider'd in several bodies: for there will arise new diversifications, from the greater or less number of the moving corpuscles; from their following one another close or at a distance; from the order wherein they follow each other; from the uniformity of their motion, or the confusion of it; from the equality or inequality of their

PHYSICS. their bulk, and the similitude or dissimilitude of their figures; from the narrowness or wideness, &c. of the channel or passage in which they move; with the thickness, thinness, pores, and the conditions of the medium thro' which they move; from the equal or unequal celerity of their motion, and force of their impulse: and the effects of all these are variable, by the different situation and structure of the organs, or other bodies, on which these corpuscles strike.

And since local motion is, next to the author of nature, the principal agent in the production of her phenomena, these diversities, in the motion of bodies, must necessarily produce a strange variety in their nature, and qualities. Thus in music, as the instrument of producing sounds trembles more or less swiftly, it puts the air into a vibrating motion, more or less brisk; and produces those diversities of sounds, which musicians have distinguish'd into notes, and subdivided; assigning to each a particular name. And tho' the bodies, from whence these sounds proceed, may be of very different natures, as wire, strings, pipes, &c. yet, provided they put the air into the like waving motion, the sound, and even the note, will be the same; which shews how much that great variety, which may be observ'd in sounds, is the effect of local motion. And if the sound come from an instrument, as a lute, where not only one string hath its proper sounds, but many have, among them, several degrees of tension, and are differently touch'd, as sometimes these, and sometimes those together, whereby more or fewer, or none of their vibrations, come to be coincident; they will so strike the air, as to produce sometimes those pleasing sounds we call concords, and sometimes those harsh ones we call discords.

Hence, then, appears the fertility of our principles. And this great variety may be produced, not only by the diversifications that each single principle is capable of; but much more by the several combinations that may be made of them; especially since our external and internal senses are so constituted, that each of those modifications may produce a distinct impression on the organ, and a correspondent perception in the discerning faculty: many of which perceptions, especially if distinguished by proper names, belong to the list of particular qualities.

The third and last difficulty that remains to be consider'd, may be thus propos'd. Since, according to the corpuscular hypothesis, not only one or two qualities, but all of them, proceed from the magnitude, shape, and contexture of the minute parts of matter; if two bodies agree in one quality, and so in the structure on which that quality depends, they ought to agree in other qualities also; since those, likewise, depend upon the structure wherein they agree; and, consequently, it seems impossible, that two such bodies should have so many different qualities, as experience shews they may. Thus 'tis pretended, that the whiteness of froth proceeds from the multitude and hemispherical figure of the bubbles 'tis made up of. And if this, or any other mechanical fabric, or contexture, be the cause of whiteness; how comes it to pass, that some white bodies are inodorous, and insipid, as the calx of hart's-horn; others, both strongly scented, and strong-

strongly tasted, as the volatile salt of harts-horn, or of blood; some dissoluble in water, as salt of tartar; others indissoluble in that fluid, as calcin'd harts-horn, &c. some fixed in the fire, as the body last named; others fugitive, as powdered sal-armoniac; some incombustible, as salt of tartar; others very inflammable, as camphire, &c. This, I confess, is a considerable difficulty in the corpuscular philosophy.

But, 1. I consider, that in the pores of visible and stable bodies, there may be often lodged invisible and heterogeneous corpuscles, to which a particular quality that belongs not to the body, as such, is to be referr'd. Thus in the case of a perfumed glove, in the pores of the leather, odoriferous particles are harboured, which have a quite different nature from the leather itself, and wholly adventitious to it; yet they endue it with a fragrancy.

2. I consider, that corpuscles often of very different natures, if they be but fitted to convene, or to be put together after certain manners, which yet require no radical change to be made in their essential structures, but only a certain juxta-position, or peculiar kind of composition, may, notwithstanding their essential differences, exhibit the same quality. For invisible changes made in the minute, and, perhaps, undiscernible parts of a stable body, may suffice to produce such alterations in its texture, as to give it new qualities, and, consequently, different from those of other bodies of the same kind or denomination; and, therefore, tho' there remains as much of the former structure as is necessary to make it retain its denomination; yet it may admit of alteration, sufficient to produce new qualities. Thus, when a bar of iron has been violently hammer'd, tho' it continues iron still, and is not visibly alter'd in its texture; yet the insensible parts may have been put into so vehement an agitation, as to make the bar too hot to be held in one's hand. And so if you hammer a long thin piece of silver, tho' the change of texture is invisible, it will acquire a springiness that it had not before. And if you leave this hammer'd piece of silver a while upon glowing coals, and after let it cool, tho' your eye will, perchance, as little perceive that the fire has alter'd its texture, as it did before that the hammer had; yet you will find the elasticity destroy'd. If on the surface of a body, a multitude of sharp and stiff parts, placed thick or close together, are protuberant, let the body be iron, silver, or wood, or of what matter you please; these extant and rigid parts will suffice to make all these bodies exhibit the same quality of roughness. And if all the extant parts of a physical superficies be so depress'd, that there is a level made with the other superficial parts of a body; this is sufficient to deprive it of its former roughness, and give it that contrary quality we call smoothness: and if this smoothness be exquisite, and happen to the surface of an opaque body, of a close and solid texture, and fit to reflect the incident rays of light undisturb'd, this is enough to make it specular, whether the body be steel, silver, brass, marble, flint, or quick-silver, &c. For besides that peculiar and essential modification which constitutes a body, and distinguishes it from all others not of the same species, there may be certain other attributes, that we call extra-essential, common to that body, with many others; and upon which
may

PHYSICS.

may depend those more external affections of the matter, which suffice to give it a particular relation to other bodies; several of which relations we style qualities. Thus, provided there be a sufficient and confused agitation made in the insensible parts of a body, whether iron, brass, silver, wood, or stone; the vehement agitation, without destroying the nature of the body that admits it, will fit it for such an operation, upon our organs of feeling, and upon bodies easy to be melted, as we call heat. And so in the instance of whiteness, it is accidental to it, that the corpuscles it proceeds from, should be little hemispheres: for tho' it happen to be so in water agitated into froth; yet in water frozen to ice, and beaten very small, the corpuscles may be of all manner of shapes, and yet the powder be white. And it being sufficient to the production of whiteness, that the incident light be plentifully reflected every way undisturbed by the reflecting body, it matters not whether that body be water or white-wine, or some other clear liquor, turn'd into froth; or ice, or glass, or crystal, or clarified rosin, &c. beaten to powder; since, without dissolving the essential texture of these, formerly, diaphanous bodies, it suffices that there be a comminution into grains numerous and small enough, by the multitude of their surfaces, and those of the air, that gets between them, to hinder the passage of the rays of light, and reflect them every way plentifully and undisturb'd. And there may be other general affections of corpuscles, besides the shape or structure of them, by virtue whereof, aggregates even of such as appear homogeneous, may exhibit different qualities: for instance, they may have some when they are in a brisk motion, and others when they are but in a languid one, or at rest; as salt-petre, when its parts are sufficiently agitated by the fire in a crucible, is not only fluid, but transparent, almost like water; tho' when it cools again, it becomes a hard and white body; butter, that is opaque, in its most usual state, may be transparent when melted; and a great quantity of beaten alabaster, which usually retains the form of a moveless heap of white powder, by being, after a due manner, exposed to heat, obtains, without being brought to fusion, many of the principal qualities of a fluid body. And if a glass be half fill'd with good spirit of nitre or *Aqua fortis*, it will, unless it be extraordinarily dephlegmed, exhibit no redness, or colour tending thereto; but if you warm it a little, or cast a bit of iron or silver therein, to put the liquor into a commotion, then the nitrous spirits putting off the form of a liquor, and ascending in that of fumes, will make all the upper part of the glass look of a deep yellow, or a red.

3. We have already observed, that a body, with regard to the production of qualities, is not to be consider'd barely in itself, but as placed in, and as it is a portion of the universe.

Lastly, as to that part of the grand objection we are clearing, which urges the difficulty of explaining, upon the corpuscular principles, how, for example, the same body, whose structure shapes it, so as to be fit to exhibit whiteness, should likewise possess several other qualities, that seem to have no affinity with whiteness; we are assisted to remove it by the past discourse: for since corpuscles, without losing the texture essential to them, may,

may, as we have shew'd, have their shape, their surfaces, or their situation chang'd; and, also, admit of alterations, as to motion or rest; as to degrees, or other circumstances of motion, as to laxity and density of parts; &c. it is certainly possible, that a single corpuscle, and much more that an aggregate of them, may, by some of these, or the like changes, be fitted to produce several other qualities, besides those that necessarily flow from it; especially, since the qualities, commonly call'd sensible, and many others too, being, according to our opinion, but relative attributes, one of these alterations, tho' but mechanical, may endow the body it happens to, with new relations, both to the organs of sense, and to some other bodies, and, consequently, with additional qualities.

If from good *Venice* turpentine, you gently evaporate about a third part of its weight, you may obtain a fine transparent, and, almost, reddish colophony. Beat this very small, it will lose its colour and transparency, and afford an opaque, and very white powder; expose it to a moderate heat, and it will quickly, without violence, both regain its colour and transparency, and become fluid; and, if whilst it is thus melted, you put the end of a reed a little beneath the surface, and dexterously blow into it, you may obtain bubbles adorn'd with very various and vivid colours. If, when it has lost its fluidity, and remains tolerably warm, you take it into your hands, you will find it has, in that state, a viscosity, by virtue of which, you may, like paste, draw it out into threads; but as soon as it grows quite cold, it becomes exceeding brittle; and, if whilst it is yet warm, you give it the shape of a triangular prism, and make it of a convenient bulk, it will exhibit variety of colours, almost like a triangular glass. Whilst this colophony is cold, and its parts are not put into a due motion, straws, and other light bodies, may be held unmov'd close to it; but if by rubbing it a little, you agitate the parts, tho', perhaps, without sensibly warming the colophony, it manifests an electrical quality, and readily draws to it straws, and other light bodies that it would not move before. Though urine be esteem'd a homogeneous body, and tho' it loses its texture by putrefaction, before it is distill'd; yet when it has been twice or thrice rectified, the spirits of it, swimming in a phlegmatic vehicle, leave a pungent saltiness upon the tongue, and a very strong and offensive smell; and when freed from the water, they are white to the eye, and exceeding sharp to very tender and excoriated parts, and burn like a caustic; so that I have seen them presently make blisters upon the tongue; and the same saline particles invisibly flying up to the eyes, prick them, and make them water; and invading the nose, often cause that great commotion in the head and other parts of the body, we call sneezing. The same corpuscles, if smelt to by a woman in hysterical fits, very often suddenly relieve her; and so may be reckon'd among the specific remedies of that odd disease. The same corpuscles taken into the human body, have the qualities that, in other medicines, we call diaphoretic and diuretic: the same particles put upon filings of brass, produce a fine blue; but upon the blue or purple juices of many plants, they presently produce a green: being put to work upon copper, whether crude or calcined, they readily

PHYSICS.

dissolve it, as corrosive menstrua do other metals; and yet the same corpuscles being blended, in a due proportion, with the acid salts of such menstrua, have the virtue to destroy their corrosiveness; and if put into solutions made with such menstrua, they have a power, excepting in very few cases, to precipitate the bodies therein dissolv'd. Now, this spirituous salt being a factitious body made out of a putrefied one, and so simple as to be a chymical salt, or one of the three chymical principles of compound bodies; it must the rather be allow'd to work by virtue of its mechanical properties. And to confirm this the more, I shall add, that if you compound it with the saline particles of common salt, which is, also, a factitious thing, and confessed by chymists to be a simple principle; these two being mixed in a due proportion, and suffer'd leisurely to combine, they will associate themselves into corpuscles, wherein the urinous salt loses most of the qualities I have ascribed to it; and, with the acid spirit, composes, as I have often try'd, a body little different from sal-armoniac: which great change, can be ascribed to nothing so probably, as to that of the shape and motion of the urinous salt, which changes the one, and loses a great part of the other, by combining with the acid spirits. And to confirm that both these happen, I have, several times, slowly exhaled the superfluous liquor from a proper mixture, made of the spirit of urine, and that of salt; and found that there remained in the bottom, a salt not only far more sluggish than the fugitive one of urine, but whose visible shape was quite different from that of the volatile crystals of urine; this compounded salt being generally figured either like combs or feathers.

And now, if to all this we add, that the extra-essential changes, which may be made in the texture, shape, motion, &c. of bodies, agreeing in their essential modifications, may not only qualify them to work immediately, after a different manner upon different organs of sense, and upon other bodies, whose pores, &c. are differently constituted; but may dispose them to receive other impressions than before, or to receive the usual ones after another manner, from the more universal agents of nature; it must appear that the proposed scruple, is not so perplexing to our philosophy, as might be at first imagined.

The three difficulties spoke to, were thought fit to be here considered, because there are many things in my other writings, which refer to the present; because the scruples themselves, are of great moment, and have not been discuss'd by others; and because the difficulties relating to the corpuscular hypothesis, in general, the solution of them may both serve to confirm several of the particulars, mentioned in giving the origin of forms and qualities, and conduce to clear and explain several other phenomena of nature.

S E C T. IX.

*Cosmical, or
systematical
qualities intro-
duced.*

THE qualities of particular bodies, for the most part, consist in relations, upon account whereof, one body is fitted to act upon others, or disposed to be acted upon by them, and receive impressions from them; as quick-
silver

silver has a quality or power to dissolve gold and silver; and a capacity, or disposition, to be dissolved by *Aqua fortis* and *Aqua regis*. And tho' in estimating the qualities of natural bodies, we usually consider only the power that any particular one has of acting upon, or its capacity of suffering from others, wherewith it is observed to have a manifest commerce, in making or receiving impressions; yet there may be some attributes belonging to a particular body, and several alterations to which it may be liable, not barely upon account of those qualities that are presumed to be evidently inherent in it, nor of the respects it bears to those other particular bodies whereto it seems manifestly related; but upon account of a system constituted, as our world is, of such a fabric, that there may be many unheeded agents, which, by unperceived means, have great operations upon the body we consider; and work such changes in it, and enable it to work such changes on other bodies, as are rather to be ascribed to some unheeded agents, than to those other bodies, with which the body proposed is observed to be concern'd. So that if many bodies, which I could name, were placed together in some imaginary space beyond the bounds of our system, tho' they would retain many of the qualities they are now endow'd with; yet they could not possess them all; but by being restored to their former places in this world, they would regain a set of faculties and dispositions, depending upon some unheeded relations and impressions from the determinate fabric of the grand system or world, whereof they are parts; and these are what I call cosmical, or systematical qualities.

I have, already, slightly touch'd upon this subject, in shewing the origin of forms, but otherwise there than I at present intend. I there, principally, observe, that one body being surrounded with others, is manifestly wrought upon by many of them: but here I shall chiefly consider the impressions a body may receive, or the power it may acquire from those vulgarly unknown, or unregarded agents, by which it is affected, not only upon the account of its own peculiar texture or disposition, but by virtue of the general fabric of the world.

The observations whereon I found my notions of cosmical qualities, are principally these.

1. There are many bodies, that, in several cases, act not, unless acted upon; and some of them act either solely, or chiefly, as they are acted on by general and unregarded agents.
2. There are certain subtile bodies in the world, that are ready to insinuate themselves into the pores of any other, disposed to admit their action, or that in some way affect it; especially if they have the concurrence of other unobserved causes, and the established laws of the universe.
3. A body, by a mechanical change of texture, may acquire or lose a fitness to be wrought upon by unheeded agents, and, also, to diversify their operations on it, by a variation of its texture.

These three propositions I shall confirm distinctly, by experiments and phenomena: but as several of the proofs may each serve to confirm more than one of the propositions, I leave them to be referr'd thereto occasionally.

Forms and Qualities.

To begin with the first proposition.

P R O P. I.

There are many bodies, that, in several cases, act not, unless acted upon; and some of them act either solely, or chiefly, as they are acted on by general and unheeded agents.

The former part of the proposition will, I presume, be easily granted, being evident from such gross instances as these, that a wedge will not cleave a block, unless forcibly impell'd against it; nor a knife attract a needle, unless excited by a magnet. But the second will not, probably, be so readily assented to.

We see however, 1. that concave specula, and convex burning-glasses, kindle not other bodies, unless enabled to do it by the reflected or refracted beams of the sun.

2. An iron bar left in a window, or some other fit place, in a perpendicular posture, tho' it was not, when first erected, endowed with magnetism, more than other iron bars of the like shape and bigness; yet after it hath long stood in that position, it will, by the operations of invisible agents, acquire a farther degree of magnetism than belonged to it as a bar of iron, and be enabled to produce some magnetical phenomena, that it could not before.

And, 3. a very flat and exquisitely polish'd piece of marble, tho' of itself it hath no power to raise any other dry body it is laid upon; yet, if it come to be carefully applied to another piece of marble, as flat and smooth as itself, and of a bulk not too unwieldy, the upper stone, by virtue of the fabric of the world, which gives the ambient air fluidity and weight, is enabled, without any other cement or fastening instrument, than immediate contact, to raise with itself, when lifted, the lower, tho', perhaps, an hundred times heavier than it.

We come now to our second proposition.

P R O P. II.

There are certain subtle bodies in the world, ready either to insinuate themselves into the pores of any body disposed to admit their action; or, by some other way to affect it; especially if they have the concurrence of other unobserved causes, and the established laws of the universe.

The antient philosophers thought there was a more subtle body than common air, called æther; and the *Cartesians* tell us, there is such a substance diffused throughout the universe; which they call, according to the different sizes of its parts, sometimes *primum elementum*, and sometimes *materia cœlestis*, which they suppose pervades all other bodies, adequately filling those of their pores that are correspondent, in bigness and figure, to the different portions of this insinuating matter. That there may be such a substance in the universe, the assertors of it, will, probably, bring for proofs, several of the following phenomena. But whether there be, or be not, in the world, any matter that exactly answers to the descriptions they make of their first and second elements, I shall not here determine; tho' many experiments seem to argue, that there is in the world, an ethereal substance very subtle and diffused. But the invisible agents I shall here chiefly take notice of, will be the air, and the magnetical effluvia of the terrestrial globe. If

If you make a bar of steel, and another like it of silver, red-hot, and put them to cool directly north and south; tho' they be both acted upon by the same agent, the fire; and tho' the steel, as to sense, seems such as it was before; yet the texture of these two metals being different, the silver acquires no new quality by what hath been done to it; but the ignition of the steel having open'd its pores, and made its parts more pliable; as may be argued from the swelling of iron heated red-hot, and its softness under the hammer; it is easily, whilst it lies north and south, pervaded by the magnetical effluvia of the earth, which glide perpetually through the air from one pole to another; and by the passage of these steams, it gains a magnetical property, which some call polarity, whereby, being freely suspended, and exactly poised, it will, as it were, spontaneously direct itself north and south, and exercise some operations peculiar to magnetical bodies. Nay, the earth has a power to impart, in some cases, a directive faculty to the load-stone itself. For having, by ignition, deprived an oblong magnet of its former attractive power, by taking it red-hot out of the fire, and suffering it to cool north and south, I could, at pleasure, by placing either end northward or southward, whilst the stone was cooling, make what end I pleas'd, point to the north-pole; and when it had done so, I could, by a new ignition, and cooling of it in a contrary position, make the same end of the stone become its south-pole.

If you take a capacious glass vial, with a slender neck ending in a sharp angle, with only a pin-hole left open at the apex, and by suction, or otherwise, free it from as much of the included air as you can; and then, having stopp'd this hole with your finger, you immerse it deep under water, and withdraw your finger; the water will, contrary to its own gravity, spring up with violence to a great height into the cavity of the vial: which motion of a heavy liquor upwards, cannot be ascribed to the motion of the finger, for that did but unstop the orifice, and not impel up the water; nor need it be attributed to nature's abhorrence of a vacuum, which it is altogether unnecessary to have recourse to in this case; the pressure of the ambient air, proceeding from its weight upon the surface of the water, being sufficient to force up that liquor into the vial, in which the remaining air, by being rarified, upon the absence of a large part, hath its spring too much weaken'd to resist the pressure of the outward air, as before: but if this experiment were try'd *in vacuo*, the water would not rise, there being no outward agent to impel it.

I had once occasion to pluck some beans and pease, out of the ground where they grew, and after having taken notice of their swelling upon imbibing the moisture of the soil, and of their way through the earth, not only upwards with their stems, but downwards with their roots; I thought fit to try with what force the causes of their intumescence endeavour'd to dilate them. Upon this, I fill'd several strong vials and bottles, with horse-beans, the intervals between the beans being fill'd with water, and the vessels exactly stopp'd with corks, strongly ty'd down, that nothing might get out: for I suppos'd, that the water soaking into the pores of the beans, would

PHYSICS. would alter the figure of the pores, and produce in them an endeavour to swell, which being check'd by the sides and stopples of the vessels, would discover, whether that endeavour were so forcible as I suspected. The success was, that most of these vessels, whether of glass or earth, were burst asunder; the strings wherewith the stopples were ty'd, breaking in the others.

To make a nearer estimate of the expansive force of the swelling beans, we put a convenient quantity of them into a strong hollow cylinder of brass, whose cavity was six inches in length, and two in diameter; then having pour'd in water enough to reach the top of the beans, we put into the upper part of the cylinder, which was purposely left unfill'd, a wooden plug made fit for the orifice, but a little narrower, that it might move freely up and down, tho' the water should make it swell. At the top of this plug, was left a thick piece of wood, broad and round, whereon we placed a common half hundred weight, which yet could not depress the plug too low, being hinder'd by the breadth of the round piece of wood. Lastly, having kept the cylinder in a quiet place, for a fit time, which is sometimes two or three days, more or less, according to the temperature of the air, and quantity of the included matter, we observ'd, that the swelling beans had very manifestly rais'd the plug, and the incumbent weight, beyond the former station.

I was willing to try whether this force would not, in cylinders of different sizes, be increas'd in a duplicate proportion to that of their diameters; but could not make such an experiment as I desired. I discover'd, however, that the pressure, upwards, was very much greater in wide cylindrical vessels, than in narrow ones; for, having put a convenient quantity of dry'd beans, into a metalline cylinder, not six inches deep, nor four broad; when the included beans began to swell, they manifestly rais'd such a plug as we just describ'd, clogg'd with above an hundred pound weight.

Whether this may pass for a new physical moving power, I shall not determine; and leave it to be consider'd, whether, by mechanical contrivances, so great a force as might this way be produced; and which slowly, and silently proceeds, till it hath attain'd its utmost energy, and is capable of being convey'd into bodies, without working any effect before the due time, may not, in some cases, be applicable to useful purposes.

We might here observe, that the air, with the æther harbour'd in its pores, may, by its constant presence, or by its being always at hand, and ready to insinuate itself, wherever it can get admittance, concur to the production of several phenomena, where its co-operation has not been suspected by philosophers. For the presence of the air, to press upon the superficies of liquors, is so requisite in suction, that they will not, thereby, be made to ascend without it; and some bodies will not, readily, be brought to putrefaction, if the air be, a-while, carefully excluded. Nay, the light which appears in some rotten woods, and in putresc'd fish, so much depends upon the presence of the air, as to disappear, if that be quite withdrawn from them; but when restored to the contact of the air, they will, again, shine as before.

But,

But, besides what the air, and the more subtle matter mix'd with it, does as a substance, it may perform several things upon other accounts; as its finer parts may be insensibly moved in strait lines, or, as it is the subject of swarms of corpuscles, put into peculiar, tho' invisible motions. For instance; if I take a sheet of paper, and rub it over with oil; that which the liquor apparently does, is only to pierce or soak into the pores of the paper; which before did, by their crookedness, or upon some other mechanical account, render the paper opake. But this insinuation of the unctuous body into the pores, having alter'd them as to figure, size, or both; and by that alteration given the paper a texture disposed to allow due passage to the corpuscles of light; the motions, or invisible corpuscles of the air, depending upon the constitution of the world, presently act upon the paper, and produce beyond it, both a sensation of light, and the representations of a multitude of objects, whence the light reflects, and which could not be seen thro' it before.

If a box be so contriv'd, that there may be, towards one end of it, a fine sheet of paper, stretch'd like the leather of a drum-head, at a convenient distance from the remoter end; where there is to be left a hole fitted for the purpose; you may, at a little hole left at the upper end of the box, see upon the paper, very lively and pleasing representations, not only of the motions, but shapes and colours of external objects. And, since upon turning this instrument, or *Camera obscura*, any way, new objects every where arise, and sometimes new landscapes upon the paper; there must be, all day long, in all parts of the air where this phenomenon is exhibited, either certain *effluvia*, emitted on all sides of the objects, or certain motions of insensible corpuscles, which, rebounding first from the external object, and then from the paper, produce in the eye, the images of these objects: so that the air is every where full of visible species, which cannot be intelligibly explain'd, without the local motions of some minute corpuscles, that, whilst the air is enlighten'd, are always passing thro' it.

I include the establish'd laws of the universe in our second proposition, as a part of the present constitution of our system; because some of those laws greatly contribute to the operation of the unheeded causes we are treating of. Thus, for instance, if you take a bar of iron, and holding it perpendicularly, apply the lowest part of it to the northern point of a well-poised magnetical needle, the bar will presently drive it away; but that magnetism, by which the bar does this, as 'tis presently acquired by the posture it had, so 'tis as suddenly changed, if you invert that posture; for if you hold the bar perpendicularly under the needle, so that the same part, which before was placed directly over the north point of the needle, comes directly under the same point; the bar will not, as before, repel, but attract it: but if this bar has been, for a long time, kept in an erect posture; as, if it be taken from some old window, or if having been heated and cooled, it has very long lain north and south; it will appear endow'd with a stronger and more durable verticity; which seems to proceed from hence, that, by lying north and south, it lay in the way, which, according to the
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PHYSICS.

establiſh'd laws of nature, the magnetical *effluvia* of the earth muſt paſs along in ſtreams from pole to pole; whereby they have the opportunity gradually to work upon the pores of the iron in their courſe, and fit them to give paſſage to the *effluvia* of magnetical bodies; in which ſitneſs the magnetiſm of iron ſeems principally to conſiſt: but if this metal had all the while lain eaſt and weſt, inſtead of north and ſouth, it would have acquired no magnetical virtue. And the reaſon why an erect poſture gives a rod of iron a power to drive away the north point of the needle, is, probably, this; that the lower end, being nearer the earth, more plentifully participates of the magnetic *effluvia*, which fly in a cloſer order there, than farther off; and, by powerfully affecting that part of the iron, turn it, for a time, into the iron's north pole; which, according to magnetical laws, ought to drive away the north pole of the needle, and attract the ſouth: whereas, if the bar being inverted, that end which was uppermoſt becoming the lower, muſt, for the ſame reaſon, have a contrary effect; unleſs, by having ſtood long, its verticity be too well ſettled, to be ſuddenly deſtroy'd, or alter'd by the *effluvia* of ſo languid a magnet as the earth. But whether this ſolution be juſt, or no, it appears, by the neceſſity both of a determinate poſition of the iron, and its long continuance in that poſition, to make the metal acquire a durable verticity, that thoſe unheeded magnetical ſtreams, which communicate ſuch a magnetiſm to the iron, move and act according to laws eſtabliſh'd in nature; which is all my preſent deſign requires.

To come to our third and laſt propoſition.

P R O P. III.

A body, by a mechanical change of texture, may acquire or loſe a ſitneſs to be wrought upon by unheeded agents, and alſo to diverſify their operations on it, by a variation of its texture.

'Tis a cuſtom at ſea, when the ſhip ſails with too ſlack a wind, to throw water againſt the ſails. At the firſt, this may ſeem a very improper means to promote the way of the ſhip, ſince there is the weight of ſo much water added to that of the veſſel; yet I have ſeen the ſeamen uſe it as one of their beſt expedients, when we were cloſely chaſed by pirates: nor is it irrational; for when the ſails are dry, a large part of the wind that blows upon them, eaſily paſſes thro' thoſe meaſhes, or large pores that are left between the threads, of which a ſail conſiſts; but being wetted, the imbibed water makes the threads ſwell every way, and, conſequently, much contracts the pores or intervals between them; whence the wind cannot paſs them ſo freely as before; but, finding a greater reſiſtance in the ſail, beats more forcibly upon it.

But farther, tho' good common tartar, uſually of itſelf, keeps dry in the air, and will not eaſily diſſolve in cold water; yet, if it be calcined, tho' but very moderately, the ſalt in the remaining coal, the texture being now altered, will readily run in the moiſt air. Having heated and cooled a loadſtone, tho' it had loſt ſo little by the fire, that the eye diſcover'd no change,
either

either in its shape or bulk; yet the operation of the fire, by changing the invisible texture, so alter'd the disposition of it, with regard to the magnetical *effluvia* of the earth, that I could presently change and alter the poles of the stone, making the same end point sometimes to the north, and sometimes to the south. The like change of verticity I have also made mere iron capable of, without the help of fire, or any other magnet, than the earth: and I find by trial, that a certain heavy stone, usually thought to be not of a metalline nature, may, by a slight and quick preparation, that alters not its bulk or shape, be enabled to attract and repel the poles of a magnetic needle.

To the instances already given in solid bodies, it will not be amiss to add two or three in fluids. If honey and water be, each of them apart, put into a convenient vessel, they will both retain their nature, and tho' you shou'd mix them together in an undue proportion, so that by reason of too much honey, the consistence be too thick; or if by being diluted with too large a proportion of water, the solution be too thin, they may still continue honey and water; but if they be duly proportion'd, as if you put to one part of honey, 4 or 5 of water, then their new texture so disposes them to be acted on by the subtile matter, or whatever other common agent nature employs to produce fermentations, that the ingredients no longer continue what they were, but begin to work like new must or wort: and I have try'd, that so small and short a local motion, as that of a coach, for a while, has so excited such a liquor, as to make it violently force its way out of the vessel, or throw out the stopple. And an eminent wine-merchant, who lived many years in the *Canaries*, assured me, he had there several times observ'd, that if a pipe of the best sort of canary were, when it was about a month old, rudely roll'd, tho' but the length of a hall or gallery, so transient and slight a discomposure of the texture, would quickly make so great a change in it, that often a large quantity of wine would be violently thrown out at the bung; or, if the pipe were too close stopped, it would have its head, or bottom, beat out.

We have numerous instances of the cracking of common glass, when it is, too soon after being removed from the fire, exposed to the cold air, and the subtile bodies that are in it; which would not have crack'd it, if it had cooled more slowly, so that its parts might have had leisure to settle into a texture, convenient for the passage of those subtile bodies; which, in that case, would have freely pervaded it. But I have, sometimes, given a more quick and manifest instance of the importance of the present texture of a body, with regard to the universal and invisible causes, that may work upon it: for having heated a plate of copper red-hot, and then suffer'd it to cool a little, on some less hot part of the fire, so that it might not appear at all ignited when removed, to a sheet of paper; yet, upon its being exposed to the atmosphere, the superficial part would not only crack as a glass hastily cooled, but presently fly off in numerous flakes, and not without noise; so that, in a short time, I have had the surrounding part of the paper, on which the plate rested, almost quite covered with little scales,

PHYSICS. as it were, of that metal. And the *Bolonian* stone, by calcination, acquires this property, that if exposed to the sun-beams, or other strong light, it will, in a few minutes, appear luminous; and, for some time, continue so in the dark.

S E C T. X.

Cosmical suspensions as to some unobserved laws and orders of nature.

I Have had some faint suspicion, that besides those more numerous and uniform sorts of minute corpuscles, which are by some of the modern philosophers thought to compose the æther, there may, possibly, be some other kind of corpuscles fitted to produce considerable effects, when they find bodies proper to be wrought on by them. But, tho' 'tis possible that these effects may be plausibly explain'd by the æther, as 'tis already understood; yet, I suspect they are not solely due to the causes assign'd them, but, in some measure, to the corpuscles above-mentioned.

In the æther of the ancients, there was nothing taken notice of but a diffused and very subtile substance; yet we are, at present, content to allow, that there is always in the air a swarm of steams, moving in a determinate course betwixt the north and south poles; which we should not probably have dream'd of, if our inquisitive *Gilbert* had not happily found out the magnetism of the terrestrial globe. And few, perhaps, would have imagin'd, that when a hunted deer has swiftly passed over a little grass, he should leave upon it such determinate, tho' invisible *effluvia*, as will, for many hours, so impregnate the air as to betray the individual flying and unseen deer, if there were no blood-hounds, whose peculiar organs of scent those steams are fit to affect. And 'tis strange, there should be such *effluvia* for a long time residing in the air, that tho' our senses discern them not, and tho' they have no operation upon other men; yet, if they meet with persons of a peculiar temper, who having formerly had the plague, thereby obtain a peculiar disposition that fits them to be affected by pestilential steams, they may so operate upon them, that these persons shall be able to discern those steams to be pestilential. Above three months before the great plague began in *London*, in the year 1665, there came a woman to a physician of my acquaintance, to desire his advice for her husband, whose chief distemper, she said, was a swelling in his groin; and added, that he was confident the plague would rage vehemently in *London* next summer. His reason was, because in the last great plague he fell sick of that disease, and then had a pestilential tumour; and because two other less plagues were each of them preceded by a rising in his body; and now having a great tumour in the fore-mention'd place, he doubted not but it would be follow'd by a raging pestilence. This I had from the Doctor himself, a person of great veracity.

Fabricius Hildanus records of himself, that having had a pestilential tumour during a plague that happen'd in his youth, if, for many years after he chanced to go to, or even pass by a house infected with the plague, he was

was admonish'd of the particular disease that reign'd there, by a sensible pain in the part where his tumour had been.

That curious observer of the phenomena of diseases, at the famous siege of *Breda*, where he practis'd much among patients afflicted with malignant and pestilential diseases, was, at length, himself infected; upon which he tells us, "it well deserves to be remark'd, that the admonition of nature may prove very serviceable in preventing the plague. I observ'd in myself," says he, "when I visited such as were infected, that I presently felt a pain in my groin, or arm-pits; sometimes my head was seiz'd, and then I sweat in the night, and afterwards had three or four stools: others also assured me, that the like happen'd to them." And here the judgment of these two writers, the profession they were of, and their relating things that often happen'd to themselves, may well gain credit to what they say: These instances, added to what has been already said, may make it proper to consider, whether there are not other, and unobserv'd sorts of *effluvia* in the air, about which, to declare a positive opinion, is not what I pretend to.

And, as I take in the structure and establish'd laws of the universe, to account for the cosmical attributes of things; I must here confess, that I fear we have not yet attentively consider'd either of the number, or the kinds of those laws.

I am inclin'd to think there may be a greater number of the more general laws, than have yet been distinctly enumerated. When we speak of the establish'd laws of nature, in the more popular sense of that phrase, I imagine they may be justly and commodiously distinguish'd; some of them being general rules, that are very extensive, and of greater affinity to laws, properly so called; and others seeming to be not so much general rules, or laws, as the customs of nature, in a particular part of the world; of which there may be a greater number, and these may have a greater influence on many phenomena of nature, than we usually imagine.

But as the structure of the world is a great help to our present inquiry, I shall venture to say, that tho' I admire the industry of astronomers and geographers, yet they have presented us rather a mathematical, than a physical hypothesis of the universe; having shewn us the magnitudes, situations, and motions of the fix'd stars, and the planets, without being solicitous to declare what more simple and compound bodies the globe we inhabit may consist of. And as, of late, the discovery of the four planets about *Jupiter*, with the phenomena of comets, have made a reformation in the theory of the celestial bodies; so future discoveries may, perhaps, reduce us to make changes in the grand system of the universe itself; and in that which we consider as the most important of the mundane bodies to us, the terraqueous globe.

What communication this may have with the other globes we call stars, and with the interstellar parts of the heavens, we know but very little. I confess, I have sometimes suspected, that there may be in the terrestrial globe itself,

PHYSICS.

itself, and the ambient atmosphere, several laws, or customs of nature, that belong to this orb, and may be denominated from it, which yet, seem to have been either unknown, or overseen, both by scholastic and mathematical writers.

And, first, I have often suspected, that there is in the mass of the earth, some great, tho' slow internal change; from considering, that almost in all countries, where observations have been made, there has a plain and considerable alteration appear'd in the variation, or rather, declination of the magnetic needle; which is the distance by which the needle declines east, or west, from the true north pole. Near *London*, the compass declined in the year 1580, above 11° ; in the year 1612, above 6; in the year 1633, about 4; and it has, of late, been found to have little or no variation. And, at a place within half a league of *London*, trying with a long and curious needle, purposely made and pois'd, I could scarce discern any declination at all: and if the needle declined sensibly any way from the pole, it seem'd to do so a little more towards the other side, than that towards which it declined before. And having, in the year 1669, by the help of an exact meridian line, made an observation at *London* itself, with two instruments, one whereof was extraordinary, and different from the other, I could not discern the declination of the needle to exceed half a degree. But since observations of this kind may prove more considerable, than we are aware of; and since they ought to be made at distant places; I shall add, that the *Cape of Good Hope* being one of the most eminent parts of the terrestrial globe, an ancient and most experienced navigator of my acquaintance, assured me, that when he was a young seaman, he observ'd the variation there to be about 2° westward; and afterwards, during many years that he sailed betwixt *East-India* and *Europe*, he found it to increase gradually. And, as he learned from ancient writings, and the traditions of old seamen, that, before his time, they had found no variation at all, he, about 13 years ago, which was the last time he took it, found it, by accurate instruments, to be 6° , and about $48'$: so that during the time he used the seas about the *Cape of Good Hope*, the variation, still westward, had decreas'd near 5° . Hence, I cannot but think it probable, that there may be agents we know not of, that have a power to give the internal parts of the terrestrial globe a motion, tho' we cannot yet certainly tell, according to what laws 'tis regulated, or so much, as whether it be constantly regulated by certain laws, or no. And what other alterations agents that can produce a change in the terrestrial globe itself, may make in particular parts of it, who can inform us?

We may, next, consider the great uncertainty, and irregularity hitherto observ'd in the weight of the atmosphere, by our new statical barometers; and much more sensibly by mercurial ones, yet without having discover'd the causes of such considerable alterations in the air; except that, in general, they proceed from subterranean steams, whose influences upon other things may be more considerable than we have yet had opportunity to observe.

'Tis

'Tis very remarkable, what M. de Rochefort, who liv'd in some of the *American* islands, relates about the hurricanes in those parts, viz. that before the *Europeans* came thither, the inhabitants observ'd they had those fatal tempests once in seven years, and no oftner; afterwards they were troubled with them but once in six years; and, at length, they grew so frequent, that, in our author's time, they return'd every year; and, as they once observ'd, twice in one year; and, afterwards, thrice in another. And, an inquisitive gentleman, who had liv'd in *New-England*, assur'd me, there was a great change made in the temperature of the climate of that country, it being grown much milder than formerly; as had been observ'd for many years after the *English* planted a colony there: the change was manifestly perceiv'd by the natives; and appear'd, also, by the slow operation of the cold upon the waters, which were formerly frozen at particular times. And, having the honour to stand by his majesty, when he receiv'd an address from *New-England*, presented by the governour of a colony there, the king asking him about the temperature of the air of that country, he reply'd, in the presence of several who came from *America* with him, that "the climate had much alter'd, and lost of its former coldness, for several years, since the *English* settled there." Whether this decrease of the sharpness of the air will proceed, or how long it will continue, time must discover. But, supposing the matter of fact to be true, and that the change depends not on any manifest cause; what has happen'd already, seems, to me, very considerable; since, in a book intitled, *New-England's Prospect*, written by Mr. Wood, one of the ancient planters of *New-England*, there is this notable passage. "In former times, the rain came seldom, but very violently, continuing its drops, which were great and many, sometimes 24 hours together, sometimes 48; which water'd the ground for a long time after; but, of late, the seasons are much alter'd; the rain coming oftner, but much more moderately, with less thunder and lightning, and sudden gusts of wind." And, again, speaking of the heathen natives, he says, "they acknowledge the power of the *Englishman's* God, as they call him, because they could never yet have the power, by their conjurations, to damnify the *English*, either in body, or goods: and, besides, they say, he is a good God, that sends them so many good things; so much good corn, so many good cattel, temperate rains, fair seasons; which they, likewise, are the better for, since the arrival of the *English*; the times and seasons being much alter'd in seven or eight years; free from lightning and thunder, long droughts, sudden and tempestuous dashes of rain, and lamentable cold winds." Hence it appears, that this decrease of the coldness, and severity of that climate, were taken notice of many years ago; for 'tis now 35 years since this book was publish'd.

Magnetis tells us, in his treatise of manna, that, in the country he calls *Cenotria*, there was no manna to be found a little above three hundred years ago. And that in *Calabria* itself, which furnishes a great part of *Europe* with that drug, 'tis but two ages since, or thereabouts, that manna has fallen. 'Tis seriously affirm'd to me, by sober persons, from their

PHYSICS. their own experience, that the spots made in linen, by the juices of fruit, and particularly of red currans in straining bags, will best wash out, and scarce otherwise, at that time of the year, when those fruits are ripe the ensuing year.

The ingenious *French* writer of the history *des Isles Antilles*, where he lived several years, speaking of the fruit they there call *Acajou*, tells us, that the juice of some of the internal parts of it, tho' reputed an excellent remedy in fainting-fits, is of such a nature, that if it chance to fall upon a piece of linen, it turns to a red spot, that lasts till the tree comes to be again in flower; which phenomena, (if the length of time, and the heat and temperature of the air, usual in the seasons of producing blossoms, and ripening of fruits, be found to have little share in their cause) may prove of some use in our present inquiry.

Whatever be the true cause of the ebbing and flowing of the sea, yet, at spring-tides, the motions of such vast masses of matter, as the great ocean, and most of the seas, are so constantly co-incident with the new and full-moon; and the more stupendous spring-tides have been, in most places, so long observ'd to happen regularly about the equinox, that it is worth an enquiry whether these conspicuous phenomena may not, somewhat confirm the conjectures we are discoursing of.

And, recollecting how many questions I have put to navigators, about the luminousness of the sea, which, in some places, shines in the night, as far as the eye can reach; at other times and places, only when the waves dash against the vessel, or the oars strike, and cleave the water; that some seas shine often, and others have not been observ'd to shine; that, in some places, the sea has been observ'd to shine, when particular winds have blown, whilst, in other seas, the observation holds not; and that in the same tract of sea, within a narrow compass, one part of the water will be luminous, whilst the other is dark: I say, recollecting many of these odd phenomena, which have been told me by very credible eye-witnesses, I am tempted to suspect, that some cosmical law, or custom of the terrestrial globe; or, at least, of the planetary vortex, may have a considerable share in the production of such effects.

Nor am I sure, that some subterranean change, or some yet unobserv'd commerce between the earth, and other mundane globes, has not an interest in the origin, continuance, and cessation of those diseases the physicians call new, which invade whole countries, and sometimes greater portions of the earth, and last very many years, if not some ages, before they become extinct.

I shall mention but two suspicions more, about the establish'd laws and customs of nature. The first is, that I doubt those thought the grand rules, whereby things corporeal are transacted; and which suppose the constancy of the present fabric of the world, and a regular course of things, are not altogether so uniformly comply'd with, as we presume; at least, as to the lines, according to which, the great mundane bodies move, and the boundaries of their motions. For what reason the wise author of nature pleas'd to permit,
that

that she should be sometimes, as it were, over-ruled by the exorbitant motions of bodies, I must not, in this place, enquire: but, when I consider the nature of brute matter, and the vastness of the bodies that make up the world; the strange variety of those bodies which the earth comprizes, and others of them may well be presum'd to contain; and when I, likewise, consider the fluidity of that vast interstellar part of the world, wherein these globes swim; I cannot but suspect, there may be less of accuracy, and of constant regularity, than we have been taught to believe, in the structure of the universe. And, to pass by the irregular motion of the sun, whence, by the observation of the exactest astronomers, natural days are not all of equal length; this bright luminary, from time to time, not only vomits out great quantities of opaque matter, call'd his spots, some of them bigger, perhaps, than *Europe*, or *Asia*, but has had almost his whole face so darkned with them, that, for a year together, he suffer'd, as it were, an eclipse. Add to this, the comets, their number, vastness, duration, odd motions, and other phenomena; and 'twill appear, that even in the celestial part of the world, all is not so regular and unvariable, as men have been made to believe.

I might here declare, that with regard to certain black and white clouds, said to move as regularly in the antarctic hemisphere, as the neighbouring stars themselves, I have been assur'd, by the captain of an *East-India* ship, who lately ventur'd upon unfrequented parts of the south-sea, that he had often seen, in the southern hemisphere, in the complement of the circle of the milky-way, two or three places appearing like clouds that moved with the white part of the circle, regularly about the earth in 24 hours. But, by his account, I suspect, that the black clouds, said to appear in this quarter, are no more than a kind of perforations, or parts of the azure sky in the milky-way; for, the colour of them, he said, was not black, but a deep blue. The white clouds, called, also, the *Magellanic* clouds, he said, he had often seen towards the south-pole, moving about it in 24 hours; and that he began to discover them in about 18° south latitude; that they were really white, and three in number, tho' two of them be near each other; the greatest lying far from the south-pole; but the other, not many degrees more remote than the conspicuous star, said to be nearest the same pole; that is, about 11° distant from it; tho' there is, also, said to be one of the fifth magnitude, not 3° distant therefrom. But, perhaps, these supposed clouds, if view'd thro' a good telescope, would appear to be constellations of small stars, singly invisible, like those in the galaxy, the belt of *Orion*, &c.

On the other hand, we may, perhaps, take such things for exorbitances and deviations from the settled course of nature, as, if long and attentively observ'd, will be periodical phenomena of very long intervals. But, because men have not sufficient skill, and curiosity to observe them, nor a life long enough to be able to take notice of a competent number of them, they readily conclude them to be but accidental extravagancies, that spring not from any settled, and durable causes. For, the world, like a great animal,

PHYSICS. mal, producing some effects but at determinate seasons; if the first man had lived but one year in the world, he would, perhaps, have thought the blooming of trees in the spring, and their bearing fruit in the summer, accidental; and have look'd upon an eclipse of the sun, as a prodigy of nature; observing, that though at every new moon, the sun and she came very near together; yet neither before, nor after, was there any such terrible phenomenon consequent thereupon. And we ourselves may easily remember what strange conjectures we had of the several various appearances of *Saturn*, for several years after our telescopes first discover'd them.

But most remarkable is that celestial phenomenon, afforded us by the emerging, disappearing, and re-appearing stars of this age, which have been observ'd in the girdle of *Andromeda*, and in, or about the swan's breast; and, especially that, which having, about 25 years ago, appear'd for a while, in the whale's neck, among the fixed ones, and afterwards, by degrees, disappear'd, was look'd upon, by the astronomers of that time, who did not out-live it, as a comet: but, afterwards, an ingenious *English* gentleman, of my acquaintance, having observ'd here, the return of the like phenomenon, in the same part of the heavens, it caus'd much wonder: since when, the famous *Bullialdus*, and others, have taken notice of it, in the same place. Now, these observations, and especially, the last disappearance of a star, judg'd to have been plac'd among the fixed ones, and estimated to be of the 4th magnitude, have somewhat confirm'd me in the suspicion I am now upon. For, if this, and the other new stars, continue to return, periodically, to the same part of the heavens, where they have been already seen, as, at least, in this its gradual increase, after it began to shew itself, and decrease afterwards, seem to promise; then I may, with more probability than before, suspect that there are vortices beyond the surface of what we call the firmament: which suspicion, if true, would much discredit the hypothesis we now have about the system of the world; and favour what I conjectur'd, as possible, about periodical phenomena. However, if either the new star, without departing from its place, be only sometimes, by degrees, overspread, and hid by spots, like those of the sun, which are afterwards, also, dissipated; or if it have a dark hemisphere, as well as a light one; or rather a greater part of its globe obscure, than luminous, as *Bullialdus* ingeniously conjectures, and by turning slowly about its own axis, sometimes obverts to our eyes its luminous, and sometimes its dark part; there will be reason to question, the great uniformity imagin'd in the celestial bodies, and motions; and to countenance what has been propos'd about periodical mutations in the mundane globes; especially since these phenomena argue, that even those stars we call fix'd, and have look'd upon as invariable, are subject to mutations great enough to be taken notice of by our naked eyes, at so immense a distance.

A

Fundamental Experiment

MADE WITH

N I T R E;

Salt-petre, either in its rudiments, or disguizes, is to be found in so great a number of compound bodies, that it seems to be the most universal of salts; and, consequently deserves the strictest examination, in order to discover the nature of other bodies, and to improve several parts of natural philosophy.

Having, by the usual way of solution, filtration, and coagulation, reduced common nitre into crystals, we put four ounces of it, thus purified, into a strong new crucible; wherein we melted it into a limpid liquor, and, whilst it was in fusion, cast into it a small live coal, which presently kindled it, and made it boil, hiss, and flash for some time: after this, we cast in another glowing coal, which made it fulminate a-fresh; and, after that, a third, and a fourth; and so continued the operation, till the nitre would neither fulminate, nor be kindled any more. Then we continued to keep it in a strong fire for above a quarter of an hour, that if any volatile part should yet remain, it might be forced off. And now taking out the crucible, and breaking it, whilst it was hot, we divided the remaining fixed nitre, into two equal parts, and dissolved one in as much fair water as would just suffice for that purpose; then dropp'd on it spirit of salt-petre, till the ebullition ceas'd; and, after filtration, expos'd it in an open vial to the air: and to the other portion, not dissolved, we dropp'd, likewise, of the same spirit, till the hissing and ebullition wholly ceas'd; and then expos'd this, also, to the air, with the former. The event was, that the mixture wherein we employ'd fair water, shot, in a few hours, to the lower-part of the sides of the glass, some saline particles, which seem'd, by their form, to be salt-petre; amongst which, nevertheless, there appear'd to swim very little grains of some other kind of salt. The crystals were, the next day, taken out, being by that time, grown somewhat larger, and more numerous; and, upon trial, they discover'd themselves to be truly nitrous, both by their

The experiment.

burn-

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PHYSICS. burning and shape. The figure of the crystals of refin'd, unanalyz'd nitre, I found, upon examination, to be not cylindrical, but each appear'd to have six flat sides, of unequal breadth; any two of the opposite ones, being commonly parallel. The remaining liquor, being pour'd into an open glass, and left in the same window, continued for five or six days without any considerable alteration; but, at the end of that time, there began to appear very fine crystalline *Stria* of petre, which gradually grew more numerous for a fortnight longer. A great part of the other mixture, wherein no water was employ'd, subsided in the form of salt, over which there swam a little liquor, that seem'd to keep the subsiding particles from congealing into one coherent mass; and part of this salt, being taken out, and dried in the air, appear'd not very regularly figur'd, yet resembled the shape of salt-petre; and, cast on a quick coal, imitated the deflagration proper to nitre. The remaining part of this salt, together with the liquor swimming upon it, we kept, for about a month, in the open air, without discerning any change, till towards the latter-end of that time, when it coagulated into small saline masses, whose figures were not discernible; and, therefore, dissolving the whole in a little fair water, and filtering it, we found, after evaporation, about one half of the salt shot into fine crystals, figured like those of petre, tho' somewhat different in taste, but burning upon a live coal like them: and the remaining half of this solution being hastily exhaled, let fall its salt in a figure not reducible either to that of salt-petre, or of any other determinate kind.

Observations
upon making the
experiment.

To render this experiment the clearer, let it be observ'd, (1.) That a fresh coal is not to be thrown in, till the detonation, occasion'd by the former, be almost ended, unless the matter blows that too soon out of the crucible. (2.) That the spirit of nitre requisite to be dropp'd on, amounts not quite to so great a weight as the salt-petre loses in its detonation. (3.) That the fixed nitre, thus made, differs but very little from vulgar salt of tartar, in lixivate taste, in its aptness to attract the moisture of the air, and its other more obvious qualities; only, as salt of tartar is white, this was of a deep colour, betwixt blue and green, which yet, upon the affusion of the spirit of nitre, vanish'd; tho' some sort of calcin'd nitre will, of itself, obstinately retain that colour.

But, for a more expeditious way to re-produce nitre, we run its fixed salt *per deliquium*, which, after filtration, immediately shot, with the spirit of nitre, into true nitrous crystals: but because, in dry weather, this salt is long in running, we have done the same thing with a solution of fixed nitre, fair water, and some portion of the spirit. And lest it should be suspected, that these crystals proceeded from some particles of nitre, yet lurking in the salt after fixation, we have produced the same from common potashes, and *Aqua fortis*.

Deductions from
the experiment,
as to the cause
of heat and cold.

Hence we see, that motion, figure, and disposition of parts, with the like primary and mechanical properties of matter, suffice to produce those more secondary affections of bodies, which are called sensible qualities. And to begin with heat and cold; it is commonly supposed, that salt-

salt-petre is one of the coldest of bodies; yet the parts of it, viz. its spirit and fixed salt, put together, immediately agitate each other, with vehemence, and produce a great heat; as if that quality were nothing but a various, and brisk motion of the minute particles of bodies: for the heat continued as long as this confused agitation lasted, and with that agitation it increased, or abated; and at length, when the motion ceased, the heat, also, vanished.

Upon the mixture of the two above-mention'd liquors, there was, also, *Sounds.* produced a very audible sound, not unlike that of a live coal in water; and this hissing was accompanied with an effervescence and boiling, till the bubbles were ready to flow over the vessel. The sound seem'd to proceed from the sudden and smart percussions of the air, made by the swift and irregular motion of the particles of the liquors; for it increased and grew faint in proportion to their ebullition. And such a kind of noise, but much louder, was produced by casting a live coal upon the salt-petre. What interest such a smartness in striking the air hath in the production of sound, may, in some measure, appear by the motion of a bullet, and that of a wand, which produce no sound, if they slowly pass thro' it; but if the one smartly strike the air, and the other be shot out of a gun, the celerity of their percussions puts it into an undulating motion, which produces a considerable sound. This noise ended long before the heat; to produce the latter whereof, such an intestine tumult of the parts of many bodies will suffice, which is yet unable to produce a sound: as we see in amber, or good hard wax, heated by rubbing; and in many liquors, that retain a considerable degree of heat long after the expiration of the noise they made in boiling.

The diversification of colours is observable in many instances, as well as *Colours.* in this experiment. And the like change we have, sometimes, observed in fixed nitre, upon leaving it in the moist air. The copious fumes arising from the mixture, would make the unfill'd part of the glass of a reddish colour; which is not more odd, than that those of distill'd foot should appear as white as milk. A sublimation, likewise, of sal-armoniac, and antimony, exhibits a strange variety of colours: but, in making a nitre from pure salt of tartar, and *Aqua fortis*, there arose a deep green colour. And, nitre itself, yields, in distillation, blood-red fumes, which fall again into a liquor that manifests no redness at all.

Upon the mixture of these two liquors, there is, also, produced a very *Odours.* strong and offensive smell. But tho' the spirit of nitre hath an ungrateful odour, of itself, yet it is made much more offensive, by being pour'd on its own fixed salt. The odour of the fixed nitre is very languid; but that which it discovers, when dissolved in a little hot water, is wholly different from the offensive scent of the other; being of kin to that of alkalizate salts. And yet the salt-petre, from which such differently-scented bodies proceed, and which may again emerge from the coalition of them, has no smell at all.

PHYSICS.

Tastes.

Again, the tastes of these two bodies, are as different as any of their other qualities: the fixed nitre has as strong a taste of salt of tartar, as the spirit has of distill'd vinegar; yet these two bodies both spring from, and unite into salt-petre, which betrays upon the tongue, no heat, nor corrosiveness. And tho' the renew'd salt-petre had, at first, a taste more sharp than ordinary nitre, yet that pungency may, probably, have proceeded from some acid particles of the spirit, not duly incorporated with the nitrous parts.

Inflammability.

Farther, this experiment makes it questionable, whether inflammability strictly requires a sulphureous ingredient; and whether it may not result from such a contrivance of parts, as disposes them to be put in motion by the adventitious corpuscles of another body, so as to exhibit what we call flame.* How violent a heat is producible upon such an account as this, may appear by a mixture of filings of iron, and spirit of nitre; which will presently begin to penetrate the metal, disjoin, shake asunder, and scatter its parts, with great rapidity, upon which a strong heat ensues; tho' the same spirit will calmly run camphire into an oil, without manifesting any conflict.

Our experiment, also, informs us, that salt-petre may be produced by the coalition of two bodies, which are neither of them inflammable. 'Tis observable, that upon casting nitre on a glowing coal, or upon the casting a glowing coal into that when melted, the nitre will immediately take fire, and flash out into bluish flames; but, if the same nitre be placed in a crucible, which shall, by degrees, be made glowing hot, the salt will be thereby melted, but not kindled.

Fluidity, and firmness.

It may also deserve enquiry, whence salt-petre, which when committed to distillation, is very well dried, sends over spirits into the receiver, that do not, as sal-armoniac, and some other bodies, distill'd with the like heat and vessels, adhere in the form of sublimate, but fall into a liquor that coagulates not in the cold. The like enquiry may be made, concerning the fluidity of the distill'd spirits of decrepitated salt, calcin'd vitriol, &c. which seem to have been destitute of moisture, when committed to distillation.

Volatility, and fixedness.

Again, tho' good spirit of nitre wastes itself in a sensible exhalation, yet, when it is once re-united to its own fixed salt, it emits no such steam, tho' long kept, near a considerable fire; which shews how the more active parts may be entangled, and hindred from escaping by those which are more sluggish. Farther, upon dropping the acid spirit into the alkalizate liquor, you may plainly discern the saline particles toss one another to a great height, into the air, whence most of them fall back into the vessel, like a thick shower of little

* "Do not, (says Sir Isaac Newton) all fix'd bodies, when heated beyond a certain degree, emit light, and shine? and, is not this emission perform'd by the vibrating motions of their parts? And, do not all bodies, which abound with terrestrial parts, and especially

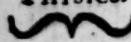
with sulphureous ones, emit light as often as these parts are sufficiently agitated, whether that agitation be made by heat, or by friction, or percussion, or putrefaction or by any vital motion, or any other cause? See Newton. Optic. p. 314.—319.

drops.

drops. And that these particles are saline, is manifest from those which fall on the outside of the glass, settling into little grains of salt. And that there is a very brisk agitation in the particles of the spirit of nitre, appears from hence; that upon pouring *Aqua fortis*, whose active part is little else than spirit of nitre, upon salt of tartar in fair water, the acid spirit will sever the particles of salt with such impetuosity, that the bubbles produced upon their conflict, ascending in swarms, make them appear like so many little rising springs.

And it may be useful to observe the difference betwixt those active parts of a body, which are of differing natures, when entangled with others in the texture of a concrete; and the same particles, when set at liberty: for tho' in the intire body of salt-petre, its ingredients act but very languidly, yet we see with how great an activity both the acid spirit, and the fixed salt, are separately endow'd. And we may yet farther observe, that it is not barely an activity of the particles of saline liquors, which enables them to produce their particular effects; for, to the production of some of these there seems requisite, besides a modification of their motion, a determinate figure of the corpuscles, answerable to that of the pores of the body, to be dissolved by them: thus spirit of nitre corrodes silver, but not gold; tho' when its particles are associated with those of sal-armoniac, whereby it acquires a new figure, and, perhaps, a different motion, it will readily dissolve gold. And the liquor of fixed nitre will, for the same reason, dissolve such sulphureous bodies as the acid spirit will not touch. Nay, there may be liquors, which will not dissolve some bodies, unless the motion, or activity of their particles, be allay'd, or modified by the mixture of fair water, or such unactive vehicles.

Our experiment farther shews us, the unwariness of those chymists, who confidently ascribe to each of the ingredients, or principles of a concrete, the virtues and properties of the intire body; for, herein we may observe, that when salt-petre is distill'd, the volatile liquor, and fixed salt, into which it is reduced by the fire, are endowed with properties exceeding different both from each other, and from those of the undissipated concrete: for, the spirit of nitre is a kind of mineral vinegar, and possesses the common qualities to be met with in acid spirits; tho' the fixed nitre is of an alkalizate nature, and participates of the qualities generally belonging to lixivate salts. And salt-petre, itself, is discriminated by distinct properties, both from those salts which are eminently acid, as alum, vitriol, sal gem, &c. and from those that are properly alkalizate, as salt of tartar, and pot-ashes. Accordingly, we may easily observe a vast disparity in the effects and operations of these three bodies. For several, if not all of those mineral ones which *Aqua fortis* will, by corroding, dissolve, the solution of fixed nitre-precipitates; and several, if not all, of those sulphureous bodies, which the solution of fixed nitre-dissolves, the acid spirit of salt-petre will precipitate. Thus, if into a scarlet tincture of brazil in fair water, we pour a little spirit of nitre, the liquor will, in a moment, change its redness for a yellow; which, by pouring on it a little of the solution of fixed nitre, may be again rais'd to a sanguine colour, sometimes paler,

PHYSICS.  paler, and sometimes deeper than the first: whereas, a solution of salt-petre, pour'd into either the red, or the yellow tincture, has not been discern'd to produce any sensible effect. And as salt-petre is partly fixed, and partly volatile, the acid ingredients of it are wholly volatile, and the alkali-
lize fixed.

*The generation
of nitre.*

We may, also, from our experiment take occasion to enquire, whether the air doth not contribute to the artificial production of salt-petre; for the salt, which was leisurely permitted to shoot in the liquor, expos'd to the open air, shot into more fair and large *Stiria*, than those obtain'd from the remaining part of the same liquor, by a more hasty evaporation. And when we pour'd *Aqua fortis* on a strong solution of salt of tartar, till no farther effervescence was discernible, it would not shoot into so fair crystals of petre, till it had been long expos'd to the open air. But whether the air really contributes any thing, either to the production, or figuration of salt-petre, in our experiment, I dare not yet determine; because, first, the figuration seems not owing so much to the proper efficiency of the air, as to the conveniency of a competent vehicle for the crystals to move in, and conform themselves to that figure which is most natural to them. For the fixed nitre, which was not dissolved in water, before the affusion of the acid spirit, did not shoot into the usual form of crystals of petre, but remain'd a kind of nitrous powder; being necessitated, for want of room, to make an over-hasty coalition; and, therefore, differ'd from those, into which the saline corpuscles would have dispos'd themselves, had they been allow'd a competency of vehicle, and time. And, secondly, I forgot to try, whether part of that liquor, which shot into crystals in an open glass, expos'd to the air, would not have done the like, if it had been left quiet, as long as the other was, tho' in a vessel accurately stopp'd. But whatever the air hath to do in this experiment, we have known such changes made in some saline concretes, chiefly by help of the open air, as very few would be apt to imagine.

*The forms of
bodies.*

But if, upon farther tryal, it appears, that the whole body of salt-petre, after distillation, may be adequately re-united into salt-petre, equi-ponderant to its original self, this will afford us a noble instance to shew, that what is commonly called the form of a concrete, which gives it its being and denomination, and from whence all its qualities are supposed, in the vulgar philosophy, to flow, may be, in some bodies, but a modification of the matter they consist of; whose parts, by being particularly dispos'd, with relation to each other, constitute a determinate kind of body, endowed with peculiar properties; whereas, if the same parts were otherwise dispos'd, they would constitute other bodies of very differing natures from that of the concrete, whose parts they formerly were; and which may again be produc'd after its dissipation and seeming destruction, by the re-union of the same component particles, associated according to their former disposition. The renewal of an analyzed body, accurately, and really perform'd, may give great light to many particulars in philosophy. And tho' in this experiment of salt-petre, even as we have already made it, there is not an
exact

exact and adequate restoration, it is yet not far from being a real one; the dissipated parts of the concrete truly re-uniting into a body of the same nature with the former, though not altogether of the same bulk.* It may be requisite to observe, that salt-petre is no very compounded body; and therefore others, which consist of more numerous ingredients, cannot be safely judg'd of by what is possible to be performed on that: for, even wine, we see, when its spirit is, by distillation, drawn from it, will not, by the re-union of its constituent liquors, be reduced to its pristine nature; because the workmanship of nature, in the disposition of the parts, was too elaborate to be repaired by the bare apposition of them to each other again: besides, in the act of dissociation, even by the gentlest fire, some active particles will, perhaps, undiscernibly vanish, whose presence was requisite to preserve the concrete under its determinate form; as we see wine degenerate into vinegar, upon the avolation of some subtle sulphureous spirits, not to be perceiv'd by any sensible diminution of the liquor. And, certainly, there is so artificial a contrivance of particles requisite to the constitution of the organical parts of living bodies, that it will be scarce possible for human art to imitate those productions: and, therefore, I wonder not that the story of the *Phenix* reviving out of her own ashes, should pass for a fiction. And if what *Kircher* relates, as an eye-witness of the re-production of shell-fishes, near a lake in the *Sicilian* promontory *Palore*, by watering their broken bodies with salt-water, in the spring, be strictly true; it seems much more improbable, that such changes should be bare restorations, than that they should be new productions, made by some seminal particles, lurking in the destroy'd body, and afterwards excited by a gemial heat to act upon, and organize a disposed matter, according to the exigencies of its own nature. For that, in some bodies, the seminal particles may, a-while, survive the seeming destruction of life, is not without example. And, in *Kircher's* story it is to be observ'd, that the restored animals were but shell-fish, in whose viscous substance, the spirits, and prolific parts, are, probably, more diffused and preserved: and we may add, that in such fish, the mechanical contrivance is but very plain and slight, compared with that of more perfect animals.

The last observable, we shall at present take notice of, in our experiment, is, that some chymical remedies may be too rashly rejected by physicians, because corrosive liquors have been employ'd in their preparation; on a conjecture, that they can never be so exquisitely wash'd off, but that some of the salts must adhere to the medicine, and display their nature in the body. 'Tis true, indeed, that many ignorant chymists, either employ corrosives without any necessity, or neglect sufficiently to free their medicines from the corroding salts, wherewith they were prepared; for, fre-

Corrosiveness,
and corrosibility.

* Mr. *Homburg* having, with great care and accuracy, resolved the body of common sulphur into an acid salt, a bituminous substance, and an earth mix'd with a few metalline parts, M. *Geoffroy*, re-com-

posed these principles into true, inflammable sulphur, only substituting oil of tartar for the latter. *Memoir. de l'Academ. A.* 1703. p. 376. *Edi. Amst.*

quent ablutions will not always suffice for this purpose. But there may be several bodies, which quite alter the nature of the acid salts, employed to prepare them; by occasioning those salts to degenerate into another nature, upon the very act of corroding; or else, by so associating their own salts with those of the dissolving menstruum, that, from the coalition of both, there arises a third body differing in qualities from either. Thus in our experiment we find, the spirit of nitre, which is much more sharp than distill'd vinegar, and the fixed nitre, which is caustic, do, by their mutual action, work themselves into salt-petre; which is far from having any fretting quality, and may be safely taken inwardly, in a much greater dose than either of its ingredients. And how much corrosive salts will dulcify themselves by corroding some bodies, may easily be tried, by pouring distill'd vinegar, or moderate spirit of vitriol, upon a competent proportion of any testaceous substance. It were, therefore, worth while, in every preparation, where corrosive liquors are employ'd, to consider the distinct nature of the bodies to be wrought upon; or to consult experience, whether or no the acid menstruum communicates to the concrete any particles capable of retaining their fretting quality, after the operation is ended; or, whether the salts do not spend themselves in the act of corroding, so as to become unable to corrode any farther; or, whether the menstruum does not, in the body to be corroded, meet with some such saline particles, as may, with it, constitute a new and inoffensive substance; as when spirit of vinegar, by corroding calcined lead, is turn'd with it into a salt, not of an acid, but of a saccharine taste. In the former of these cases, the medicine may prove dangerous, unless it be, after the solution, exquisitely dulcified; but, in the two latter, the remedies may, in spite of the corrosiveness of the menstrua, be safe and innocent: for it matters not how sharp the sever'd ingredients of a remedy are, provided the remedy itself, resulting from them, be not so. It is objected, that in several of these remedies, the corrosive salts are not really destroy'd, but only disguized; because, by distillation, it is possible to separate the liquors used about them, as corrosive as ever. To this it may be easily, reply'd, that it little concerns us to be sure that out of the medicines we take, the fire cannot separate corrosive salts; provided we are duly satisfied, that no such separation can be made by the heat, or juices of a human body. And therefore, though it has been affirm'd, that *Tartarum Vitriolatum* would, with a strong fire, part with much of the oil of vitriol, which concurr'd to its production; yet our best physicians scruple not to give it internally in several distempers. And, to conclude, we clearly see, that salt-petre is frequently, and safely given inwardly; though the salt which makes even *Aqua fortis* so corrosive, be the principal ingredient of it, and may, by distillation, be driven from it.

T H E
O R I G I N
O F
Fluidity and Firmness.

S E C T. I.

WHether fluidity and firmness be not rather states, than qualities, we shall not here examine: but, as they are the most general properties of bodies, it is well worth our while to find out more satisfactory explanations of them, than we have receiv'd from the schools.

A body seems to be fluid, by consisting of corpuscles touching one another only in some parts of their surfaces; whence, by reason of the numerous spaces betwixt them, they easily glide along each other, till they meet with some resisting body, to whose internal surface they exquisitely accommodate themselves.* *A fluid, what?*

It is probable that, in many liquors, the little surfaces of the component particles are spherical, smooth, and slippery; which will greatly facilitate the rolling of the corpuscles among themselves, and, consequently, promote the fluidity of the body they compose. But, there are several other figures, which may make the little bodies endow'd with them, voluble enough to constitute a fluid substance. And the other qualities to be met with in some liquid substances, as water, and oil, seem to argue their parts to be otherwise shaped; and those fluids which are not liquors, as air and fire, seem compos'd of particles, not all of them round, but of very various, and, sometimes of very irregular figures; yet such bodies deserve to be called fluid. It is not necessary to the fluidity of a body, that the corpuscles it consists of, shou'd be crowded as close together as they are in water, and others,

* Sir Isaac Newton defines a fluid to be that body whose parts give way to any impress'd force; and which by giving way, are easily moved among one another. *Newton. Princip. p. 260.*

PHYSICS. commonly look'd upon as the only liquors. For, tho' a parcel of matter no bigger than a grain of corn, being rarified into smoke, will possess a much greater space, than it did before; and tho', if a body be farther rarified into flame, its expansion will be yet much greater; yet both smoke and flame, may be made to appear like liquors. Thus in blowing a mouthful of the former through a glass pipe, to fill it, and, afterwards, stopping the other end, on any inclination, it will settle, by degrees, to a level superficies, parallel to the horizon. And, as for the latter, I have so prepared copper, with sal-armoniac, that a few small grains of it, put into the wick of a burning candle, would give a very durable flame, perfectly green; which kept distinct from that of the candle, as if there had been some invisible partition between them.

*The requisites
to fluidity, viz.
smallness of
parts.*

The conditions of a fluid seem to be, chiefly, these. First, a smallness of the component particles; for bulk is apt to render them too heavy, to give way to those causes which make fluids move so freely among themselves. Lead, quick-silver, and, even gold, though, whilst they are of a sensible bulk, they will readily sink to the bottom of *Aqua regis*, or any other such liquor; yet, when the menstruum has corroded them into very minute parts, they grow so much more capable of agitation than before, as to be freely carried every way: nay, ponderous bodies may, by division, be render'd so light as to become ingredients even of distill'd liquors. Butter of antimony, though a very limpid liquor, will, with fair water, precipitate a heavy, white calx, reducible to glass.

But to shew yet more particularly, that bulky bodies are unfit to constitute fluid ones, we may observe how nature, as well as art, in order to render them such, makes a comminution of them; as in the stomachs of dogs, to reduce bones into chyle, by some peculiar fluid; in imitation of which, I made a certain liquor, whereby I have, in a short time, and without fire, dissociated the parts of bread, flesh, fruit, &c. and reduced them to the consistence of fluids. Nor is a great quantity of an appropriated liquor requisite to the digestion of the aliment. Common water, the usual drink of most animals, as particularly dogs, wolves, &c. appears, of itself, very unfit to dissolve bones, &c. even by boiling; and many sorts of creatures, particularly camels, may, even in hot climates, be brought to travel, for many days, without drinking. I am familiarly acquainted with a gentleman, who usually drinks but once in several days; and then, no excessive draught: and once, in particular, he continued about nine days, without taking in, or requiring any liquor; and might have continued much longer in that state, had he not distemper'd himself by hard study; and, even then, one small draught serv'd him for about four days longer. This gentleman, too, is in the flower of his age, and of a florid and sanguine complexion; he sweats freely, eats as other men; and his urine in quantity, is like that of others of his age and temper. We see, likewise, that fusion makes metals fluid; which cannot be done whilst they continue in masses of any sensible bulk: and even melted metals may have their fluidity increas'd, by a yet farther comminution of their parts.

And

And as to the enquiry, whence it happens, that in the distillation of dry saline bodies, there will be obtain'd a perfect liquor, it may, indeed, be said, that in several dry bodies, such as hartshorn, wood, and bones, the fire does no more than separate the aqueous parts from the others, and bring them together into the receiver ; but this doth not reach the difficulty, because the thing holds in bodies already calcined, such as the calx of vitriol, fluxed sea-salt, &c. which yet afford liquors, tho' their aqueous, and looser parts, have been driven away by a strong fire, before they were exposed to distillation. Perhaps, then, the vehement agitation produced by heat, both divides such bodies into minute corpuscles, and drives them over into the receiver ; where, losing their former agitation, they are reduced into a liquor, chiefly because the fire has rent the concrete into parts, which, by their extreme minuteness, by their figure, or by both together, are fitted to be so easily moved, that the usual agitation of the air, propagated thereto, or the same cause that gives the air its agitation, is able to keep them fluid.

Viewing a glass of the chymical oil of aniseeds, that stood frozen, by the cold season, in a window, I immediately melted it, poured a particular liquor upon a part of it, placed in another glass, and suffer'd the rest to cool in the same vessel that contain'd it before. When this was fully cool'd, I found it again congeal'd, as usual ; but the other continued fluid, both day and night, and in several changes of weather ; and still remains at the bottom of the menstruum a clear oil distinct from it, though I have often shaken them together. And having slowly evaporated good clear *Venice* turpentine, till the remaining part afforded a fine colophony, I reduced some of this transparent gum to fine powder, and put a greater proportion of it into pure spirit of wine, than the liquor was able to dissolve, that a quantity of the colophony might remain at the bottom ; whereby I obtain'd a sluggish liquor, that continued fluid as long as the menstruum was left upon it : but, when the glutinous liquor was separated from the menstruum, it would gradually harden in the air. And whilst this substance was fluid, I could not by shaking, make it truly or lastingly unite with the spirit of wine.

That, also, some bodies will be kept fluid, by a much less degree of agitation than others require, seems probable from hence, that wine will continue a liquor in such a languid warmth of the air, as cannot keep the parts of water moving, but permits them to rest in the form of ice. And, in cold countries, where wine itself congeals, though the more aqueous parts will there, by loss of motion, be turned into ice, yet the more subtle, and spirituous, remain unfrozen. And tho' cold may very much condense even air, yet, that it hath never been frozen by any degree of cold whatever, seems to proceed from the extreme smallness, and peculiar figure of its parts, giving way to the least agitation.

An ingenious teacher of mathematics, having occasion to make a composition for a new fire-engine, whereof he was to shew his Majesty a trial, mingled divers ingredients in an earthen pot, over kindled coals ; but

PHYSICS. could not, or did not, do it so warily, but that the matter took fire, and began to blaze furiously; which obliged him to stifle the flame as hastily as he could: and having remov'd the vessel from the fire, and suffer'd it to grow cold, when afterwards he came to look upon it, to see if what remain'd might be of any use to him, he was surprized to find it variously and briskly moved. Wherefore, having set it aside, to be sure that it might be thoroughly cold, he, after some hours, visited it again, and found it move as before. And, having cast store of seeds upon it, to see if the liquor would move them also, the bituminous part of it connected them into a kind of thick scum, that cover'd most of the superficies; but yet left some intervals, in which the liquor appear'd, and discover'd that it continued its motions. Two days after, the engineer discoursing of his fire-work, about which he had advis'd with me before, told me of this odd accident. And alledging that the motion continu'd still, my diffidence, or curiosity, made me engage him to send for the pot as it was; partly to be sure of the matter of fact, and partly to try if the knowledge I had of the ingredients, would afford any hint as to the cause of so odd an effect; a like to which, in kind, tho' not in degree, I had many years before seen, and successfully practis'd the way of producing.

The vessel being come, there appear'd manifest signs of such a motion as the engineer had ascribed to it; and therefore I caus'd it to be set aside in a laboratory, where some furnaces kept the air constantly warm, and did there, and elsewhere, at distant times, look heedfully upon it, now and then displacing, or quite taking off some of the thick scum, that too much cover'd the surface of it; and by this means, I had the opportunity to take notice of several phenomena, whereof these are the chief.

1. I observed, that the motion of this liquor was not only brisk, but very various; so that having loosen'd some small portions of the scum from the rest, one of them would be carried towards the right-hand, for instance, and another towards the left, at the same time. 2. Where the liquor came out first from under the scum, it seem'd to move the most briskly, flowing almost like a stream, whose motion upwards had been check'd, and, as it were, reverberated by that incumbent obstacle. 3. Several motions in this liquor were the more easy to be observed, because, tho' it were dark, yet it was not uniform, consisting, in part, of oily, and bituminous ingredients, which, tho' they seem'd to have but one common superficies with the rest of the liquor, yet, by their colours, and vigorous power of reflecting the light, they were easily distinguishable from the rest. And I often observed, that some of the unctuous portions of the matter, emerging to the surface of the liquor, tho, perhaps, at first, one of them would not appear bigger than a pin's head; yet, in moving forwards, it would, at the same time, diffuse itself circularly, and make, as it were, a great halo, adorned with the colours of the rain-bow; and so very vivid, as afforded a pleasant, and surprizing spectacle; these phantasms often nimbly succeeding one another, and lasting till they lost themselves against, or under the thick scum. 4. The motions of this odd liquor were not only various, but

but frequently vortical; to be satisfied of which, I sometimes put short bits of straw, or fragments of some such like stuff, upon the discover'd part of the surface of the liquor, by which they were carried towards very distant, if not opposite parts of the vessel at the same time. But to make the vortical motion more evident, I several times detached considerably large pieces of the thick scum from the rest of the body; and had the pleasure to see them move, both with a progressive motion in crooked lines, and with a motion about their own middlemost parts. All this while the liquor, whose parts were thus briskly moved, was actually cold as to sense. 5. To observe what the presence, or absence of the free air would do to this liquor, I caus'd many spoonfuls of it, with some of the scum, to be put into a cylindrical glass, which, tho' large itself, had a neck belonging to it, which was but about the bigness of one's thumb, that it might be well stopp'd with a cork. But, having by this means, kept the free air from having a full, and immediate contact with the whole surface of the mixture, as it had when that mixture lay in the wide-mouth'd vessel; I could not perceive the liquor to move to and fro; no, not tho' the orifice of the neck were left open: whereas, having, at the same time, pour'd some of the liquor into a very shallow, and wide-mouth'd vessel, it moved rather more nimbly and variously than in the great earthen pot, (which yet was of the same shape) and shewed us many vivid, and self-dilating circles. 6. Tho' the motions of the liquor did not seem to be always equally brisk, yet they appear'd to continue manifest and various in some diversities of weather, as to cold and heat, and when I look'd on it by candle-light, as well as by day-light. 7. I kept some spoonfuls of this liquor close stopp'd in a vial, and so had the opportunity to observe, that when I pour'd out the liquor into a wide-mouth'd vessel, it would move as before, tho' this were done some weeks after it had been put up. About the beginning of *June*, that is, about five months, or more, after the liquor was first observed to move, to gratify the curiosity of a foreign minister, and that of some other ingenious men then present, I caus'd the vial to be brought, and having unstopp'd it, I pour'd out the liquor in a conveniently shap'd vessel; in which, after we had suffer'd it to rest a-while, they were delightfully surprized to see it move (tho' not in my opinion quite so briskly as before) very manifestly, and variously. This encouraged me to think it possible, that it might retain some motion, though but languid, seven or eight weeks after; and accordingly I then look'd upon it again; and having caus'd it to be pour'd into a china cup, it manifested, at first, a brisk and various motion. But this, after a-while, so slacken'd, that I began to have some suspicion, the motion it was put into by the effusion, and the first contact of the air, might have given it the greatest part of its agitation; but this was only suspicion.

To proceed; it is, likewise, possible, that a saline spirit may consist of very minute grains of salt; for, a sal-armoniac may be made by spirit of urine, and spirit of salt, as the common sal-armoniac is with crude salt; and the urinous one, as strictly as it here seems united to the other, may be readily separated

PHYSICS. rated from it. And, as common *Aqua fortis* may be enabled to dissolve gold, by the addition of spirit of salt; so common crude salt, barely dissolved in it, will give it the like power of working upon gold: nay, crude nitre, dissolved in good spirit of salt, may make it serve for an *Aqua regis*. And, the most noted person in *Holland*, for distilling corrosive bodies, affirmed to me, that he had, by using brick-dust, sand, &c. sometimes brought over almost the whole body of salt into a liquor; so that from a pound, he has easily obtain'd no less than twelve ounces of a spirit, after it had been well rectified. And *Beguinus* teaching the distillation of another salt, adds, that if you have wrought well, you shall get from a pound of the matter, a pound of spirit. But because from all these liquors, it is possible to obtain a portion of phlegm, or water, I leave it to farther trial, whether their fluidity may not, in many cases, be advanced, by being diluted with water.

A determinate
figure of them.

We may add, that the shapes, as well as the sizes of bodies, contribute to their fluidity. For tho', in sal-armoniac, antimony, &c. which are by the fire sublimed into flowers, rather than distill'd into liquors, the magnitude of the component corpuscles may not, perhaps, be a hindrance to the fluidity of the body they constitute; yet this seems as probably owing to their figure, as to their bulk. I have, by slowly distilling common olive oil *per se*, in a glass retort, found about a third part of the oil, which was driven over into the receiver, coagulated into a whitish body, almost like butter. So that altho' distillation can obtain liquors, even from consistent bodies, in this experiment of a concrete naturally fluid, the distill'd liquor itself proved not to be so; of which no cause seems more obvious, than that the newly acquired shape of the dissipated parts of the oily corpuscles, makes them unfit for motion, either absolutely, or, at least, in respect of one another, by rendring them less pliant, or giving them a figure more easy to be entangled with the neighbouring corpuscles; or else, by making their surfaces less smooth and slippery than before.

'Tis observable of bodies, which consist of incoherent parts, that those, in being poured out, most resemble liquors which are the smallest; as would appear, upon the emptying of several sacks of apples, walnuts, filberts, corn, sand, and flower. They who make much use of whites of eggs, will easily reduce those viscous bodies into a thin and fluid substance, like water; yet this difference of fluidity, being effected only by long beating, seems to be produced but by pulling asunder the parts, and breaking them into shorter, less, and, consequently, more voluble ones. And I have seen that jelly, which is sometimes found on the ground, and call'd by the vulgar a star-shoot, resolved by digestion only, into a permanent liquor; which an eminent physician, of my acquaintance, extols as a specific, outwardly applied to wens. Goldsmiths observe, that when any curious work of silver is to be cast, it is not enough, that the silver be barely melted, but it must be kept, for a considerable time, in strong fusion: for, if it be too soon poured out, the figure it makes, will be blunt; but, if kept a competent time in fusion, the matter becoming thereby more liquid, will

will be thin enough to run into the smallest cavities of the mould, and so receive a figuration, even from the most delicate of them : whence it is probable, that some bodies already fluid, may, by a farther comminution, be made yet more fluid. And, the like increase of fluidity may be observed in some other bodies, especially unctuous ones, as turpentine, oil, &c. when heat begins to break, as well as agitate their parts. And, by long digestions, with a due degree of heat, there may be made in the parts of many bodies, both vegetable and animal, so great a change, from the state of consistence, to that of fluidity, as those who content themselves with ordinary courses of chymistry would not expect.

Another requisite to fluidity, is, that there be many vacant spaces betwixt the component particles of the body. I need not here require absolute vacuities ; 'tis sufficient that between the solid parts, there be nothing but what will easily yield to them, and not resist the freedom of their motions. To illustrate this, let it be observ'd, that snow, which, at its first falling, is of a loose, and open texture, easily yields to the impressions of the hand ; but when, by being strongly compress'd, the little icy bodies, of which it consists, are brought into a closer order, and many of them thrust into the little spaces, before possess'd only by the yielding air, they will not give way to the motions of the hand, as before, but compose a hard and resisting body. However, the existence of vacant spaces, or some yielding matter about the corpuscles of a fluid body, seems requisite, only as it obviates that impediment to their motion, which exquisite fulness might prove. And tho' in such bodies as water, wine, oil, quick-silver, &c. this condition may take place, yet it is not absurd to question, whether there may be no portion of matter, consisting of parts so minute, and so agitated, as incessantly to change places among themselves, and thereby constitute a very fluid body, without any vacuities, receptacles, or yielding matter about them, unless on the external parts of those, which, from time to time, happen to be at the surface.

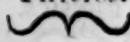
But the last, and chief condition of a fluid body is, that the particles of which it consists, be agitated variously, and a-part, by their own innate motion ; or by some thinner substance, which shall toss them about in its passage thro' them. For, this seems to be the principal difference betwixt solid ice, and fluid water, that in the one the parts being at rest, resist those endeavours of our fingers to displace them, to which, in the other, the parts being already in motion, easily give way. For, whereas in the ice, every part actually at rest, must, by the law of nature, continue so, till it be put out of it by an external force, able to surmount its resistance, to a change of its present state ; in water, each corpuscle being actually moved, we need not begin, or produce a new motion in it, but only direct that which it has already. From this agitation of the parts of fluids, those minute bodies, to continue their motion, glide sometimes over, sometimes under, and sometimes by the sides of one another. And hence appears the cause of softness in fluid bodies, that is, their yielding to the touch ; for, the particles which compose them, being small, incoherent, and variously moved,

PHYSICS. moved, it is easy to thrust them out of those places, which, being already in motion, they were disposed to quit; especially when there are vacant spaces at hand, ready to admit them, as soon as they are displaced. And hence it likewise happens, that these little bodies must be very easily moveable any way upon the motion of the mass, or liquor they compose; and that being very small, and moving so many ways, they are very unfit to bound themselves, but very easy to be bounded by any other firm body, which hinders them from spreading any farther; and yet to continue their various and diffusive motion as much as they can, they must necessarily move to and fro, till their progress be stopp'd by the internal surface of the vessel; which, by terminating their motion, obliges the liquor exactly to accommodate itself to whatever figure that shall happen to be of.

Experiments to
illustrate and
confirm the do-
ctrine of fluidity.

This general account of fluidity may be farther illustrated, and confirm'd by the following instances and experiments. Salt-petre may be made fluid either with or without a liquor. And first, it puts on the form of a fluid body, by solution in water, which entering the pores of the salt, disjoins, and divides it into parts so small, that it is easy for those of the water, where-with they are associated, to support and move them. But fixed nitre, exposed to the moist air of a cellar, will run *per deliquium*, into a liquor, which consists of no more aqueous particles than are necessary to keep the saline ones in the agitation requisite to fluidity. The fluidity it is capable of, without a liquor, may be of two kinds: for, first, if it be beaten into an impalpable powder, this, when it is poured out, will resemble a liquor, though its fluidity be imperfect. But if, with a strong fire, this powder'd nitre be melted, then each of the saline corpuscles, being sub-divided, and variously agitated, the whole body will appear a perfect liquor: and such is the fluidity of melted metals. And not only fire is able to make hard bodies fluid; for some may be render'd so by others, which to the touch seem cold, if they are but fitted to change the texture of the hard body, and put its parts into a convenient motion; as appears in turning camphire into an oil, by letting it lie upon *Aqua fortis*. Camphire may, also, by a dextrous application of heat, be brought, in close glasses, both to flow, and to boil almost like oil. It is true, such liquors taken from the fire, quickly grow solid again; but the duration of a thing is not always necessary to denominate it: for the leaf of a tree, whilst it flourishes, may be as truly green, as an emerald; though the leaf will, after a while, wither and turn yellow, which the stone will not. And, in cold climates, lakes, &c. are frozen hard, notwithstanding the same portion of matter was, a little before, a fluid body, and will be thaw'd into a liquor again.

It may be requisite here to observe, that the fluidity, acquired by salt-petre upon fusion by fire, seems of kin to that which it acquires by solution in water; for both will appear to be caused by the pervasion of a foreign body: only in dissolution the fluid is a liquor, and consequently more gross; whereas, in fusion, the fluid substance, that permeates it, is more thin, divides it into much smaller parts, and adds very little to its bulk. And it is a notable experiment to this purpose, which I have made with



with finely powder'd alabaster, or plaister of *Paris*; for putting it in a bason over a fire, it will, when hot, assume the appearance of a fluid, by rolling in waves, yielding to the touch, steaming, &c. all which properties it again loses on the departure of the heat; and being thrown upon paper, will not at all wet it, but immediately discover itself to be as moveless an incoherent powder, as before it was set over the fire: whereby it appears, that a heap of such little bodies, as are neither spherical, or otherwise regularly shaped, nor small enough to be below the discernment of the eye, may, without either fusion, or being poured out, be made fluid, barely by a sufficiently strong and various agitation of the particles which compose it; and, moreover, lose its fluidity immediately upon the cessation thereof*.

Hence we see how much it conduces to the making of a body fluid, that its small parts be actually moved; but whence this motion proceeds, we shall not, at present, venture to determine: since not writing elements of philosophy, but concerning fluidity, which is only a secondary, or derivative quality, it is sufficient, that we deduce it not from the unintelligible substantial forms of the bodies, but from those simple and general properties of matter, the figure, situation, and motion of its small parts†.

There is yet one thing more, to be learnt from salt-petre, as to the nature of fluidity, and that is the distinction between a fluid body, and a wetting liquor; which, because they agree in many things, are usually confounded: for tho' every wetting liquor be fluid, yet every fluid body does not wet. The air, the æther, and even flame itself may, properly, be called fluid bodies; yet will scarce by any one be termed moist liquors: salt-petre, whilst in fusion, is really a liquor, and so is every melted metal; yet these wet not the bodies they touch, like water and other liquors which are fluids, with this peculiar qualification, that they stick to and moisten the dry bodies in contact with them: so that the humidity of a body is but a relative thing, and depends chiefly upon the congruity or incongruity of the component particles of the liquor, with regard to the pores of those bodies it touches; as may be exemplified in quick-silver, which cannot be said to be a humid body in respect of almost all other bodies, upon whose surfaces it will roll, without leaving any of its particles lodged in their pores; but with regard to several metals, especially gold and tin, it may be called moist, for it insinuates itself into their pores, and thereby mollifies their bodies, as other liquors do to other dry substances. And even water, which wets almost all animal and vegetable bodies, seems not a humid liquor in respect to the feathers of water-fowl. And it is observable, that upon the change of tex-

Intestine motion requisite to fluidity.

The difference between a fluid body and a wetting liquor.

* 'Tis remarkable, that M. *Homburg*, having set some oil-olive to digest, for two months, upon quick-silver, the oil, in that time, became so thick and hard, that the mercury underneath wanting, as he supposes, that freedom of motion which is necessary to its fluidity, became like a perfect solid mass, tho' of itself it was not

fixed; but appear'd fluid again, upon being taken out of the vessel. *Hist. de l'Acad. A. 1708. p. 80.*

† We must here observe, that what Sir *Is. Newton* demonstrates of fluids, seems to make against the necessary existence of any such actual motion in their parts, as is here supposed. See *Newton. Princip. p. 260, 261.*

PHYSICS.

ture in a liquor, it may be brought to stick to the surface of a body, on which before it would not fasten; for tho' quicksilver alone will not adhere to glass, yet if there be mixed with it a due proportion of lead, tin, and tin-glass, tho' neither of these will stick to glass, yet their liquid mixture readily does, even without the assistance of heat.

Farther proofs
of intestine mo-
tion in fluids.

If it be objected, that this various agitation of the insensible parts of water, and the like bodies, wherein we make the nature of fluidity chiefly to consist, is but an imaginary thing, and precariously asserted, since the particles themselves are so small, that they, and the diversity of their motions are imperceptible by sense; it may be replied, that the particles whereof liquors consist, being too small to be visible, and being not only voluble, but in actual motion, the pores or vacant spaces between them, must, also, be too little to be discerned by the eye, and, consequently, a fluid body must appear an uninterrupted or continued one. 'Tis true, a heap of grains of nitre, tho' upon its effusion out of the vessel, it somewhat resembles a fluid body, does yet, when it rests in the vessel, appear to be but an aggregate of many little incoherent bodies laid together; because the intervals left between them, are great enough to affect the sense: but if the same salt be reduced into an impalpable powder, the particles and intercepted spaces, being then extremely lessened, the body they make up will much more resemble an entire mass, tho' view'd at a less distance; and so when this powder is, by the fire, farther broken into parts incomparably smaller than those of the powder, and which, consequently, intercept extremely little pores, why should we deny that these may be little enough, not any where to discontinue the body as to sense? And that the incoherent parts of fluids are also variously agitated, tho' our senses cannot discern it, may be proved by their sensible operations. For without such local motion, how could the particles of water penetrate into the recesses of bodies, and occasion those putrefactive alterations, usually imputed to superfluous moisture? And how comes it else to pass, that aqueous liquors so readily mix with one another? And, without this, how could sugar, or salt, cast into them, be instantly so perfectly dissolved and diffused every way*? This is evident particularly in sea-salt; which, when the superfluous liquor is sufficiently exhaled, begins

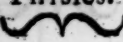
* This solution of salts in water Sir I. Newton accounts for from another principle. "If," says he, "a very small quantity of any salt, or vitriol, be dissolved in a great quantity of water, the particles of the salt, or vitriol, will not sink to the bottom, tho' they be heavier in *specie* than the water; but will evenly diffuse themselves into all the water, so as to make it as saline at the top, as at the bottom. And does not this imply, that the parts of the salt, or vitriol, recede from one another, and endeavour to expand themselves, and get as far asunder as the quantity of water will allow? And

does not this endeavour imply, that they have a repulsive force, by which they fly from one another, or at least, that they attract the water more strongly than they do one another? For as all things ascend in water, which are less attracted than water, by the gravitating power of the earth; so all the particles of salt which float in water, and are less attracted than water, by any one particle of salt, must recede from that particle, and give way to the more attracted water." *Newton. Optic.* p. 362, 363.

visibly

visibly to coagulate upon the surface of the water. And not only salt, but even gold itself, may have its parts so diffused by the agitation of these liquors; as may be easily try'd, by putting a little of the solution of gold made in *Aqua regis* into 15 or 20 times as much fair water; which will all, thereby, be immediately ennobled with a golden colour. That the little bodies whereof flame consists, are fiercely agitated, often appears even to the eye, and will scarcely be denied by him, who considers its operations. And that the particles which compose our common air, are also variously agitated, we are induced to believe, by several particulars; as, by those little motes we see floating up and down in the sun-beams; by the tremulous motion, which that of swarms of little bodies in the air, seems to impart to distant objects, view'd after sun-rise through a good telescope; and by the fusion of salt of tartar in the air; which would not happen, if the moist vapours, that help to constitute it, did not move about therein; and were not thereby brought to the salt, and enabled to insinuate themselves into its pores, and, by that means, dissolve, and reduce it, with themselves, into a liquor. And, even in summer, when the air is drier, than at other seasons, we may discover plenty of aqueous corpuscles floating in it; from their gathering in drops upon glass, and such hard bodies, wherein any cold thing is contain'd. Whence useful hints may be taken, of catching a salt and liquor out of air, barely by glass vessels of a peculiar and skilful contrivance. And experience has taught us, that it is not difficult, by a convenient furnace, to make even lead ascend to a very great height in the open air, in the form of smoak. And tho' quick-silver be, excepting gold, the heaviest known body in the world; yet, when it is reduced into vapour, it seems to be carried to and fro, like other particles, which swim in our air: for an expert gilder complained to me, that its fumes would often lay hold of his gold rings, and change them white.

But let us return to visible liquors, and see whether their insensible parts may not be every way agitated, tho' their motion be seldom visible. Dissolve any quantity of ordinary coin'd silver in *Aqua fortis*, pour the solution into twelve or fifteen times as much fair water; and then decant, or filtre the mixture, that it may be very clear. If you look upon this liquor, the parts of it will seem to be, all of them, as perfectly at rest, as those of common water: nor will your eye be able to distinguish any corpuscles of silver swimming in the liquor; yet, that there are such metalline corpuscles agitated to and fro, with and by those of the water, will quickly appear, if you immerse into it a flat piece of clean copper; for you shall see the particles of silver fasten themselves in swarms to the copper-plate, and cover it with a loose case of silver, easily to be shaken off in the form of a metalline powder: and if several such plates be left all night in the bottom of the vessel, you may, the next day, find all the particles of silver, that were dispersed through the whole body of the liquor, settled upon them; a deep bluish green tincture appearing in the water, and proceeding only from some little parts of the copper dissolved by the menstruum. And, to compleat the experiment, I have made even these fall to the bottom of the vessel,

PHYSICS.  sel, by leaving a lump or two of spelter there for two or three days: for not only those metalline corpuscles, that were just over, or near to the determinate place, where I put the spelter; but all the rest, into how remote parts soever of the liquor diffused, settled upon it; as appear'd both by its increase of bulk, and by their leaving the water clear and colourless: which plainly seems to have proceeded from hence, that the particles of the water were restlessly, and every way agitated; and so, by frequently gliding along the surface of the spelter, carry'd thither the corpuscles of the copper mixed with them, some at one time, and some at another, till, at length, all were brought to it, and detained there.

But farther, to try this agitation in spirit of wine; I let fall into a wide-mouthed glass, fill'd with that liquor, a little common oil of turpentine; and the drops swimming at the top, continued to move to and fro, in an irregular pleasing manner, for above half an hour; till the spirituous parts being blown away, they rested upon the remaining fluid, as they would upon common water. I repeated the experiment, with the same success, in another inflammable liquor; and found, not only that the oil, but some small straws also, gently let fall upon the surface of the spirit, were tumultuously carried about thereon. And this agitation of the minute parts, not only holds in light and spirituous liquors; but that the insensible parts, even of the heaviest fluids, are also in actual motion, will follow from what has been deliver'd of the nature of fluid bodies: and may be confirmed by this; that as three of the heaviest liquors, we yet know, are quick-silver, oil of tartar *per deliquium*, and oil of vitriol; the first will, even in the cold, enter the pores of gold, and destroy its texture; the liquor, also, of salt of tartar, will, in the cold, draw tinctures from several bodies; and the agitation in oil of vitriol appears, from its corroding metals, and dissolving camphire without heat. Whoever yet doubts, whether the parts of these two oils, as they are called, are fiercely agitated, may, probably, be soon satisfied, by shaking a little of them together, and observing the heat, hissing, ebullition, and sparkling that will suddenly ensue.

But though it be essential to fluids, that their parts easily shift places; yet this is to be understood, only as to the parts of the same fluid, as water; or of such different ones, as are disposed to admit each other's particles, and unite together as water and wine: otherwise, they may be of such different natures, that, when two or more of them are put together, they will not mix, but each retain its own distinct surface; as is obvious in oil, which mixes not with water; and quick-silver will not incorporate with any of the common liquors.

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As to the cause why these liquors retain distinct surfaces, I shall here only observe, in general, that it seems to depend very much upon the texture of them, and, perhaps too, upon the peculiar motions of their minute parts. For though pure spirit of wine, and salt of tartar resolved into a liquor by the air, will, when put together, retain distinct surfaces, or presently regain them, tho' you shake the liquors ever so strongly together; yet, by adding a little fair water to either of them, the texture be-

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ing thereby altered, it will easily incorporate with the other. And thus, tho' common spirit of turpentine will not mix with spirit of wine; yet, if skilfully drawn, with a very gentle fire, they may, by shaking, be united. And again, tho' lixivate salts and oils will not join; yet, by digesting, for some time, a solution of salt of tartar with oil of almonds, I could reduce them to a soft soapy substance.

A farther difference observable in contiguous fluids, is, that some of them not only refuse to unite with others, but fashion their surfaces to determinate shapes; for having pour'd spirit of wine upon oil of tartar *per deliquium*, I found that the superficies, wherein they touched, was flat, or parallel to the horizon: but if this were done in a very narrow glass, with the mouth open, tho' the lower surface of the spirit of wine, which touched the other liquor, appear'd very level; yet the upper superficies, contiguous to the air, was very manifestly concave. And if to these two liquors, in a broader glass, oil of almonds were poured, it would sink to the bottom of the spirit of wine; and, floating upon the oil of tartar, separate the two liquors; and, both above and below, retain a flat or level surface. But if, instead of oil of almonds, I dropped into pure spirit of wine, swimming upon oil of tartar, some common oil of turpentine, this oil would gather into parcels; which, in case they swam in the spirit of wine, and touched neither of its surfaces, seem'd globular; and continued so (the glasses being stopp'd) for many hours: but if they emerged to the upper part of the spirit of wine, as much of them as lay immersed in the spirit, appear'd round; and continued so as long as I pleas'd; the upper parts only of those little globes appearing to have the same surface with the spirit. I farther observ'd, that some small drops would constantly rest upon the superficies of the oil of tartar, touching it but in a point, and continuing to the eye spherical; tho' the surface of the liquor were, now and then, purposely shaken. But I more particularly observ'd, that having, into pure spirit of wine, let fall some large drops of oil of turpentine; they, at first, sunk to the bottom of it, and lay upon the surface of the oil of tartar, almost like hemispheres, whose convex part was all above the oil of tartar: but, after a while, they were press'd on all sides, and fashioned into round bodies. I took equal quantities of common oil of vitriol, and common oil of turpentine; and, very gradually putting them together, obtained an opaque, and very deep-colour'd mixture, whose consistence was much thicker than either of the liquors which compos'd it. And to shew, that the disposition of these liquors, to unite thus soon together, depended much upon their texture; we warily distilled the mixture, and obtained a certain gross substance, which seem'd to mediate the former union betwixt them: for this substance being separated, and thereby the texture of one of the fluids, or perhaps both, being changed, the liquors, which came over very clear into the receiver, swam upon one another: nor have I since been able, by shaking them together, to confound them, for any considerable time; but they presently part again, and, to this day, remain both distinct, and transparent. Now; drops of water, quick-silver, and other fluids, seeming to be fashioned into

PHYSICS. a round figure, by the equal pressure of the ambient air; I thought proper to intimate, how some experiments might be made to account for the figuration of the more considerable fluids, which make up much the greater part of the universe; especially, since, 'tis probable, that such steams of the terrestrial globe, as may well be supposed the chief ingredients of our atmosphere, may, like a liquor, retain a superficies distinct from that of the surrounding and contiguous body.

Dissolve one ounce of clean common quick-silver in two of pure *Aqua fortis*, so that the solution may be clear and total; whilst 'tis yet warm, pour in, by degrees, half an ounce, or an ounce of lead filings; and if no error has been committed, or unlucky accident intervened, the lead will immediately be precipitated into a white powder, and the mercury reduced to a mass of running quick-silver, over which will swim the remaining part of the *Aqua fortis*. Whence we see, that liquors, being reduced to very minute parts, may unite; the corpuscles of the one supporting those of the other; whilst, the texture of the one being varied, they retain distinct surfaces.

Before we quit this subject, it must be farther observed, that, not only in fluid bodies, but in some also of those which are consistent, there may, perhaps, be more motion, than our senses discern. A cluster of swarming bees, view'd at a distance, seems to be one intire body; yet each particular bee has its distinct and peculiar motions: but these motions of them all destroy not the coherence of the cluster; because, when one of the innermost bees removes, as she lets go her hold from those wheron she rested before, and quits those which rested upon her, so she meets with others, on which to fasten; and comes under others, which, in like manner, set their feet on her: so that, by this change of mutual supports, their coherence, and removes, are made consistent: and if, instead of bees, the swarm consisted of extremely minute flies, their particular motions would, perhaps, be inconspicuous. And that some such thing may happen in consistent bodies, seems probable; because, in wainscot, and other hard wood, we often see little heaps of dust, produced by putrefaction: and not only in cheese, but in apples, and other fruits, we often find maggots, tho' the rind be whole; which could not happen, unless the parts of the matter were variously transposed, and connected after a manner suitable to the nature of the insect to be produced. And, by the growth of bones in the bodies of perfecter animals, as also by the growth of the shells of oysters, and snails, from a size inconsiderable at first, in regard of what they afterwards attains to; and by some other resembling particulars, it seems that the small particles, which constitute even the solid parts of animals, are not, whilst the creature lives, exempt from some local motion. It hath been affirmed to me, by a very diligent observer, that he saw several pieces of gum sweat out of an old wainscot, that had stood above twenty years: and I have, several times, seen viscous exudations, like drops of turpentine, upon deal-boards, which had been used in buildings.

The consistence of bodies upon mixture, hard to determine a priori.

We might now discourse of the advance, or hinderance, in respect of fluidity, that one body may receive, by being mixed with another; but we shall, at present, only observe, that it is not so safe, to foretel the consistence of a mixture of two or more bodies, from the bare consideration of the consistence of those whereof it is to be compounded. And to examine what many chymists, without limitation, teach, as to the addition of salts, to metalline and mineral bodies, to facilitate their fusion, I dissolved crude copper in spirit of nitre; and, by evaporation, reduced the solution to a vitriol. We also corroded, with two parts of spirit of nitre, one of good tin, and suffered the mixture to reduce itself to a substance, almost like meal; of this mixture, we put a parcel into a crucible, and made it red-hot: we also exposed some of it to a strong naked fire, without finding it fuse at all; tho' salt-petre be a fusible salt, and tin very easy to melt. And tho' copper be of much harder fusion, not only than tin, but even than silver; yet, being joined, *per minima*, with the same kind of nitrous corpuscles, that had such a contrary effect upon tin, so strangely disposed it to fusion, that the vitriol would melt with the heat of one's hand. Nay, we have made such a vitriol, either with spirit of wine, or *Aqua fortis*, as would, even in winter, stand melted for several hours together, by the heat of the sun shining on it thro' a window. So fit it is, that we consider, as well the new texture, which mixed bodies obtain by the association of their particles, as the consistence of the particular bodies, before they are mixed.

S E C T. II.

THE chymists ascribe the firmness of bodies to salt; and tell us that is the principle of coagulation, and the cause of solidity. But tho' this opinion be so generally receiv'd, that it may seem superfluous to enquire after other causes of these qualities; yet we shall venture to consider the matter. And, having already taken a general view of fluidity, let us try what light it will afford us, to discover the nature of firmness. Now, since fluidity, and stability, are contrary qualities, they must be apprehended under contrary notions; we may, therefore, conceive, that the firmness, or stability of a body, consists principally in this; that the particles which compose it, being somewhat gross, are also at rest, and have a mutual cohesion, whereby they are rendered unapt to diffuse themselves every way: so that its three principal causes appear to be grossness, quiet contact, and an implication of the component parts.

As to the first, larger corpuscles being, *ceteris paribus*, harder to be put into motion than less, when they are once at rest; it is obvious, that a body, consisting of such particles, is less disposed to become fluid, and consequently more apt to continue firm, than if its component parts were smaller, and thereby more easy to be displaced. By gross corpuscles, I understand such as are scarce divisible into less, by the agitation of the ambient air, or any other causes of fluidity. And in speaking of the fitness of grosser

The requisites to firmness; viz. grossness of parts.

PHYSICS. corpuscles to make a firm body, I add *ceteris paribus*, because 'tis possible, that the breaking of the small parts of a body into minute particles, may the more fit them to contribute to the firmness of the body where-to they belong. For the parts of the divided corpuscles may, by their comminution, acquire a new, and perhaps a more irregular shape than before; upon which account, they might be more disposed to be entangled among the neighbouring particles, or be better fitted to get into, and fill the pores of some kind of bodies. And, in such little particles, not only the minuteness may make them lie closer together, and consequently the better exclude the air; but the greatness of the surface, in proportion to the bulk of the matter, may perhaps, in some cases, occasion a fuller contact, and so facilitate the constitution of a very firm body, in case these minute parts shall be disposed to the best advantage for a full contact with one another. But, from what was delivered of the size of parts, in treating of fluidity, it may easily be understood, how much the magnitude of them will conduce to firmness. We now pass on to the two other requisites of consistent bodies, the one whereof is the bare rest of the parts which compose the firm body; and the other, the intricate texture of such parts. And either of these seems, alone, sufficient to render a body stable; tho' nature, perhaps, often makes use of both, to fasten the parts of the same body more firmly together.

Rest and cohesion.

If two bodies be once at rest in contact, they must continue in that state, till some force, able to over-power their resistance, disturbs them. And, whatever is said of the constant mobility of atoms, yet, that several parts of matter may compose bodies, which need only juxta-position to unite them, whereby the air, or other fluids that might dissociate them, are excluded, I am inclined to think, by what I have observed in grinding of glasses: for here sometimes the convex surface of one body being ground upon the concave surface of another, the two surfaces will be so closely fitted to one another, that a man is not able, without breaking one, or both, to pull them directly asunder; but if you will sever them, you must be obliged to make one slip along the surface of the other: which makes the glass-grinders often complain of the trouble they meet with in separating such bodies. Nay, if you lay two flat glasses, ground very true, and well polished, upon one another, so that their surfaces may almost every where touch, you may, by lifting up the upper, raise the lower with it, as if the two plates of glass made but one body. And I have often taken up four or five pieces of glass at once, thus laid and press'd one upon another; and might, perhaps, have taken up a greater number. Experience also assures us, that if a looking-glass be held very level, with the unfoliated side downwards, and you rub a piece of other very flat smooth glass a little against it; you may easily, by that way only, fasten them to one another, so that the lower, tho' large, will be strangely suspended between the uppermost and the ground. And, by the same way, we have made one considerably thick piece of marble rake up another, having first caused their flat surfaces to be carefully ground. Nor is it requisite, that the glasses be flat, to make them adhere very closely together,

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provided their immediate contact be made in a large surface: for, having, purposely, applied a long glass-stopple, of an almost conical figure, and well ground, to the mouth of a thick quart-bottle, whose neck was long, of a figure convenient to receive the stopple, and ground within fit for it; we found, that these two glass-bodies, touching one another in a multitude of parts, adhered together so closely, that, when the stopple was carefully put in, we could easily lift up the bottle by it, with above a pound of liquor in it*. Yet here we must observe, that the sticking together of such bodies as are of a sensible bulk, and whose smooth surfaces immediately touch one another, may, possibly, not proceed so much from their parts being at rest among themselves; and, by their immediate contact, making up, as it were, one body; as from the pressure of the atmosphere, proceeding from the weight of the ambient air, and from a kind of spring, by virtue of which, the air continually presses upon the bodies contiguous to it; though, thro' negligence, and, perhaps, some other causes, we neither feel it in our own bodies, nor take notice of it in others. Now this pressure of the air every way, being supposed, I think the mutual adhesion of the smooth bodies we speak of, may, probably, be ascribed to this; that when the smooth surfaces of two pieces of glass, so exquisitely touch one another, that none of the ambient air, is either intercepted, or admitted between them, the under glass will suffer no pressure on that side, which touches the upper, the parts of the upper glass having no sensible spring in them; whilst that side of the under one, which is exposed to the air, will be pressed upon thereby: and there being, as we said, no elastical pressure on the other side of the glass to ballance this, no wonder that the lower glass should not fall off from the other, since the weight that would carry it downwards, is much too small to overcome that force of the air, which thrusts it against the upper glass. Thus if a man should, with his hand, thrust a plate of iron, broad-wise, against the flat ceiling of a chamber; the iron would not fall, as long as the force of the hand continues to press against it. Nor is it material, that, in our case, the pressure of the atmosphere is supposed to force the lower glass upwards: for if we suppose the air to consist of innumerable little springs, bearing upon, and supporting one another, the lower whereof are bent by the weight of all the rest, incumbent on them; it will be easy to conceive, that, near the surface of the earth, it may press almost equally every way; and by a kind of recoil, from the terrestrial globe upwards, strongly force any body, upon which it can bear, against any other, which has no such elastic power to repel a body so pressed against it.

The pressure of the atmosphere one cause of cohesion in bodies.

We shall now proceed to confirm our conjecture as to the reason why smooth bodies stick together, barely by juxta-position, or contact. And, first, tho' a piece of flat glass may be suspended by a looking-glass, held parallel to the hori-

* This strong cohesion of the parts of matter, is by Sir Isaac Newton attributed to a principle of attraction, which, in immediate contact, is exceeding strong, but reaches not far from the particles with any sensible effect. See *Newton. Optic.* p. 351—372.

PHYSICS. zon; yet, if, by inclining the looking-glass, it loseth that level, the smaller glass will slide downwards upon the surface of the greater. The reason whereof seems to be, that the gravity of the lower glass does not considerably resist the horizontal motion of it, only the motion upwards; but chiefly, because the ambient air is contiguous to the edges of the glass, as well on the one side, as on the other: and so the pressure of the air being equal on every part of the edges, the gravity of the smaller glass is not hindered, by the air, from sliding down the shelving surface of the greater: whereas, of the broad and flat sides of the lower glass, the one is, as we said, pressed by the spring of the air; whilst the other suffers no such pressure from the looking-glass, to which it was applied. And so, if you take a small open-mouthed glass, and plunge it into a vessel full of quick-silver, with the mouth upward, that the quick-silver may fill it, without leaving any air in it; and if then, whilst it is under the quick-silver, you turn the mouth downwards, and so, keeping it upright, lift it up, till the mouth be almost come to the top of the mercury; the glass will remain almost full of quick-silver, tho' the upper surface of the liquid metal in the glass be much higher, than the level of the surface of the quick-silver in the vessel: and this will continue so, tho' you incline the glass, provided you keep the mouth of it within the mercury. The experiment will also succeed, when made with water. The reason hereof seems to be, that the glass hinders the quick-silver in it from the pressure of the incumbent air; whereas, the quick-silver in the vessel being exposed to it, must, thereby, be necessarily forced up against the surface of the inverted bottom of the glass, where it meets no elastic power to drive it downwards: for that it is not nature's abhorrence of a vacuum, which keeps the quick-silver from descending, till some air can come to succeed in its room, seems clear from the *Torricellian* experiment. And to shew, that it is not so much the mere contact of bodies in a large surface, as its being ordinarily requisite to the exclusion of air, which, at least here below, keeps bodies from falling asunder; having, out of a large glass, caused a certain quantity of air to be extracted, we found, that, by immediately applying a book to the narrow orifice of the vessel, the book was afterwards readily lifted up, and sustained in the air, as long as we pleased; though the surface of the suspended body could be touched but by the ring, which incircled the orifice of the vessel; and tho' the weight taken up exceeded twenty ounces. The cause whereof seems plainly this; that, by the exsuction of some air out of the glass, the elastic power of the remaining part was much weaken'd, in comparison of the spring of the external air; which being able to press the book against the orifice of the vessel with greater force, than the internal air could resist, the mouth and lips of the vessel, on this occasion, perform'd the part of an intire surface, exactly smooth. And, by the way, upon this principle may, possibly, depend the solidity of glass: for though its parts seem not at all interwoven, and appear very smooth and slippery; yet, since the fire, which brought them to fusion, may well be supposed to have sub-divided them into very small particles, and to have thereby assisted to exclude the
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air from between them, 'tis no wonder, if the immediate contact of such small corpuscles suffices to make them hold together; for that their union is strict enough to keep out the air, appears, since the glass-blowers, and those who distil in glasses, find not that it can enter their pores. 'Twere also proper to consider, how much the juxta-position of corpuscles, crowded together by fusion, may contribute to the consistence and brittleness of salt-petre, and other bodies, which, from an incoherent powder, are readily reducible into one mass: as, likewise, how far the sticking together of the small parts of pendulous drops of water, and such other liquors as are not thought to consist of corpuscles hooked, or branched, may be ascribed to the contact of their small parts, and the exclusion of the air. But to return: tho' it be hence manifest, that the air hath a strong spring; yet, there appears no great necessity for it to shew why the two smooth glasses were able to adhere so closely. For a probable reason of that phenomenon may be assign'd from the pressure of the air, considered as a weight. And, first, we must remember that a cylinder of air, which is not without its gravity, recoiling from the earth, to the suspended piece of glass, being hindred by the resisting surface of the terrestrial globe from falling lower, must diffuse itself, and, consequently, press as well upwards, as any other way. Next, we must consider, that when the surfaces of two flat bodies, of any considerable breadth, immediately touch each other, and lie, both of them, level with the horizon; since the air cannot move, in an instant, from the edges to the middle, the lower cannot be drawn away downwards, in a perpendicular line from the upper; but, by reason of the stiffness, and contact of the two bodies, it must necessarily happen, that, at the instant of their separation, should it be effected, the lowest glass will be pressed upon by the whole pillar of air, supposed to reach from the top of the atmosphere, and to have for its basis, the superficies of the under glass. For, at that instant, the air having not time to get in between the two glasses, there is nothing between them, during that instant, to resist the pressure of that air, which bears against the lower superficies of the undermost; and, consequently, such a revulsion of the lower glass cannot be effected, but by a weight, or force, able to surmount the power of the weight of the above-mentioned cylinder of the atmosphere. Hence, we see it is not necessary, that the contiguous surfaces of the two flat glasses be parallel to the horizon; for, if held perpendicular to it, their divulsion would not cease to be difficult, provided it were attempted by suddenly pulling one of the broad surfaces from the other, in a level line, and not by making one of the surfaces slide upon the other: for, in the former case, the separation of the contiguous bodies will be hindred, by the weight, or pressure of the lateral air, which bears against the broad sides of the glasses contiguous to it. But as in these cases, we suppose the superficies of the two glasses to be so exactly flat, that no air can come between them; experience has inform'd us, that it is extremely difficult to procure, from our ordinary tradesmen, either glasses, or marbles ground near so true. We very hardly obtain'd a pair of round

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marbles,

PHYSICS.

marbles, of an inch or two in diameter, which would, for two or three minutes, hold up one another in the air by contact; tho' they would easily raise each other, if the uppermost was drawn up nimbly, before the air had time to insinuate itself betwixt them.

But to make some estimate of this power in the air; having provided a pair of marbles, an inch and half in diameter, and as flat and smooth as possible; and considering, that as it was the insinuation of the air between them, which hindered them from sticking strongly together; so the access afforded to it, was, for the most part, owing to that inequality of their surfaces, tho' polished; we supposed that the intrusion of the air might, for some time, be prevented, by wetting the surfaces to be joined, with pure spirit of wine; whilst this liquor, which seems the freest from tenacity, would not prove a cement to fasten the stones together, otherwise, than by keeping out the air. But because the easy separation of such smooth bodies, which adhere but by contact, may proceed from the least angular inclination; we try'd, in the first place, to fasten to the upper marble certain wires, and a button, so that the lower, when joined, might freely fall directly down, but not slip aside, being hindered by the wire. And thus the dry marbles were made to take up, and sustain one another; so that once, by suddenly drawing up the upper marble, we took up, together with the lower marble, a scale with a pound weight in it. After this, we moistened the surfaces of the marbles with pure spirit of wine; and keeping them, by our wires, from slipping aside, we cast into a scale, fastened to the lower of them, several weights, at several times; and, by suddenly pulling up the higher stone, often try'd how much we could draw up with the lower; and sometimes took up above an hundred ounces, and once one hundred thirty-two ounces troy, besides the scale that contained them, and the marble itself; the diameter of whose surface was only an inch and two thirds. But, because the spirit of wine proved too fugitive and subtle for our purpose, we moisten'd the surfaces with a due proportion of oil of sweet almonds; and thus we took up above four hundred ounces troy, hanging at the lower marble. It was not by glewing the marbles together, that the oil enabled them to make so much greater resistance, than the spirit of wine; for in case the flat surfaces of the joined stones were held perpendicular to the horizon, so that the air might immediately succeed, as the looser marble should slide off, the weight of several ounces was, sometimes, requisite to draw them down, when they had nothing but spirit of wine between them; tho' they would easily slide off from one another, when join'd together with oil; perhaps, because the spirit of wine, by reason of the smallness and penetrancy of its parts, and fugitive nature, did not so well fill up the little pores of the surfaces; whereby the small protuberances of the one, getting into the small cavities of the other, might more resist the sliding of the marbles upon one another's surfaces, than the oil, whose texture is better fitted to render their surfaces smooth and slippery.

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And to shew, that the resistance of such contiguous marbles, to separation, is greater in those which, being broader, are pressed against by a column of the atmosphere proportionably larger; we caused two marbles to be made, three inches in diameter: and having, after the manner above-mention'd, employ'd spirit of wine, to keep out the air from between them, we, after some tryals, with the uppermost of them took up the lower, and four hundred and seventy ounces. But making use of oil of almonds, instead of spirit of wine, we did, with our own hands, twice successively raise, with the undermost stone, thirteen hundred and forty-four ounces troy; and, at the same time, manifestly perceived the marble, at which it hung, to stick firmly to the other: yet the interposed oil was so far from being able, as a cement, to make these marbles adhere thus close together, that, in this last experiment, I made them very freely slide upon one another, by impelling the upper to the right hand, or left, with my finger; and, having some time before, raised a weight not much inferior to the last, we, presently, held the marbles with their edges downwards, and found, that, tho' in an horizontal position, they could not be separated by so great an additional weight, they now presently fell asunder by their own.

I know that the *Peripatetics*, and generality of school-philosophers, will ascribe this adhesion of marbles to nature's abhorrence, and dread of a vacuum. But if nature did so violently oppose a vacuum, it is not likely, that any force we could employ, would be able to produce one; yet, in our case, we find, that a little more weight added to the lower of the two marbles, will surmount their reluctance to separation, notwithstanding the supposed danger of introducing a vacuum thereby. But, without having recourse to any such disputable principle, a fair account may be given of the phenomenon, by the pressure, or weight of the air. Let us suppose, that when the marbles stick firmly together, the lower of them were fastened to the ground; tho' here there appears no reason, why their power to resist separation, should be less than before, yet, it seems evident, that the uppermost marble could not be perpendicularly lifted up, but by a force, that was, at least, able to raise a weight equal to that of this marble; and of a pillar of air, having the stone for its base, and reaching to the top of the atmosphere: since, at the instant of revulsion, before the air can get in between, there is, for ought appears, no body under the upper marble, to help the hand to sustain the weight of that, and the incumbent cylinder of the atmosphere, which then gravitates upon it, and, consequently, upon the hand; because there is no air, or other equivalent body underneath, to sustain its part of the weight, as the lower air does, with regard to the heavy bodies, which rest on it, and to the weight of the incumbent air. We need not therefore wonder, if when only a less weight than that of the mentioned column of the atmosphere hangs at the lower marble, it should be capable of being drawn up by the upper, rather than suffer a divulsion from it. Thus when two bodies, being fastened together, are endeavoured to be drawn asunder by forces not able to separate them, they will usually

PHYSICS. ally both move that way, towards which either of them is the most strongly drawn. And I have sometimes observed, in trying the strength of load-stones, if the load-stone be able to take up more than its own weight, you may as well lift up the load-stone by a knife, as a knife by the load-stone. And tho' one accusom'd to judge only by his eyes, would have imagin'd, that when I held the great weights, formerly mention'd, suspended in the air, there was no strong endeavour to pull the upper marble from the lower, because my hand, being for a time held steady, seemed to be at rest; yet he will easily find a great mistake therein, who shall consider, that neither did the weight sensibly appear to pull the lower marble downwards, tho' my hand assured me, that the weight had not lost its gravitation. And once, when the weight was casually so loosened from the upper marble, as suddenly to drop down, my hand, unawares, was, by the endeavour it employ'd to sustain the fallen weight, carried up with such a violence, that I bruised it against the face of a by-stander, who chanced to hold his head over the marbles.

A brass-valve, an inch in diameter, being cemented to the shorter leg of a long glass siphon, left open at the end of the other; this valve was let down to the bottom of a long glass body, full of water, till it was between a foot and half a yard beneath the surface of the water; when the water in the pipe, reach'd as high as that surface. Then, an ounce-weight was put into the scale of a balance, opposite to that whereto one end of a string was fastned; its other being connected with the valve, whose parts were thereby to be drawn asunder. Now when the water was emptied out of the pipe, and the valve let down to the former depth, four ounces of additional weight were requisite to disjoin the parts of the valve, and let the water get between. And when the valve, the siphon being freed from water, was raised gradually higher together with the pipe, less and less weight was required to make the separation; an additional half ounce proving sufficient to disjoin the parts of the valve, when held but a little below the surface of the water. From this experiment, attentively consider'd, it appears, that there certainly may be a great repugnancy, barely on account of the gravity of the medium, to the separation of smooth bodies, join'd by immediate contact. But farther, having at length suspended two coherent marbles, in a large glass, whence, by a certain contrivance, the air might be gradually exhausted; we found, whilst any considerable quantity of air remain'd in the glass, the lower marble continued to stick to the other; but if the air was farther withdrawn, the lower fell from the upper: when, if the latter were let down upon the former, whilst the glass remain'd exhausted, the upper marble might easily be raised without taking up the lower; yet when the air was let in, the marbles were again strongly pressed together, and made to cohere.

From the whole, it appears, that tho' in bodies of a sensible bulk, whose smooth surfaces touch one another, the force of the air is the principal cause of cohesion; yet, it seems, in general, a sufficient cause thereof, that the parts of the body be at rest by one another; though, perhaps, the entire

ture concretion be removed from place to place. For bodies of sensible bulk, being either fluid or consistent; and it being the chief requisite of a fluid body, that its small parts be in motion, nothing seems necessary to keep a body from being fluid, and consequently to keep it firm, but that its contiguous parts be in a state of rest. PHYSICS.

Another requisite to firmness, is the texture of the parts that constitute a body; for, tho' the juxta-position, and rest of these parts, may, possibly, alone suffice to make the body stable; yet texture seems to be the most usual cause of stability; and sometimes also, it may superadd a degree of that quality to what bodies have upon the former account only. For tho', while the parts of the body are actually at rest, it cannot be fluid; yet those parts, if they cohere to one another but by rest only, may, *ceteris paribus*, be much more easily dissociated, and put into motion by any external body, actually moved, than they could if they were, by hooks, or other kinds of fastenings, entangled with one another; it being often necessary, in this case, violently to break off these fastenings, before the little bodies, join'd together by them, can be set free, and put into such a separate motion, as is requisite to constitute a fluid body. We formerly illustrated the nature of fluidity in the white of an egg; let us now try, whether it will also assist us in our search after the causes of stability. When an egg is made hard by boiling, since nothing appears to get in at the shell, unless some calorific atoms, and perchance some small particles of water; it is not easy to discover from whence this change of consistence proceeds, unless from a change in the texture of the parts, whereby they are connected and disposed after a new manner, fit to make them reciprocally hinder the freedom of each other's motions. But if, instead of hardening the whites of eggs by the heat of the fire, you beat them into a froth, you may perceive that froth to retain the nature of a stable body; for it may be raised up into a pyramid of a considerable height. And I have made, with a little care, a long and proportionably thick body of these bubbles, hang down like an icicle from my finger, without falling: yet in these, there appears no alteration made in the fluid body, except a mere mechanical change of the disposition of its parts: which may be confirm'd by water agitated into froth; for herein the bubbles will quickly subside, and fall back into water, of the very same consistence it was of before.

Now there are several ways, whereby a body may be put into a texture, proper to make it firm; tho', for the most part, one of them is not employ'd a-part, but two or more in conjunction. The first and chiefest of these, seems to be the fitness and shapes of the component particles, to fasten them to each other; as if some were figur'd like the handles of buckets, and others like the hooks employ'd to draw them; some like buttons, others like loops; some like male, others like female screws: or, as if many together, were so variously branched, that their parts may be interwoven one within another, and not prove easily separable; thus only by twisting threads together, they are so well fasten'd to one another, as to constitute a cable, which is not to be broken without a vast force.

And

PHYSICS.

And so numerous may be the correspondent figures, fit to fasten bodies to one another, that it is very possible for two fluids, upon their conjunction, to intangle their parts, and thereby acquire such a new texture, that they cannot dissociate themselves, nor flow after the manner of liquors, but remain so connected, and unactive, as to become one entire firm body. Something like this appears, upon mixing the distill'd liquor of nitre, and that made *per deliquium* out of fixed nitre, which will thus presently coagulate into saline and stable bodies. But this seeming only a reunion of the saline particles, that swam in the aqueous parts of the mixed liquor, which, after this separation, remains both in greater plenty than the saline parts, and as fluid as before; we shall add another instance, to shew how much the firmness of bodies depends upon their texture. If you take, then, the rectified spirit of wine, and dephlegmed spirit of urine, and mix them in a due proportion, you may, in a minute, turn these two fluid liquors into a consistent body; and, I have, immediately, upon the shaking of them, seen them shoot like snow, and acquire such a consistence, that I could, without spilling the mixture, turn the vessel upside down. But this experiment will not succeed, unless both the spirits are exactly dephlegmed. Yet so much doth this coagulation depend upon the salt of urine, as being of a particular texture, and not as barely urinous, that sufficiently rectified spirit of hart's-horn may be here used in its stead; tho' even a rectified spirit, drawn from unfermented urine, hath failed of producing the same coagulation. But it is farther remarkable in this experiment, that the white substance, being put into a glass-vessel, exactly stopp'd, and kept in a gentle heat for some months, will, for the greatest part, resume the form of a limpid liquor; as if either all the crooked particles, that connected the small coalitions, were, by this means, broken off; or the same little concretions, after various attempts to get clear of each other, at length extricated themselves, and became able freely to shift their places, and form a liquor. And having digested a convenient proportion of pure *Saccharum Saturni*, made with spirit of vinegar, and rectified spirit of wine together, I found the mixture so changed in point of consistence, that, upon inclining the containing vessel, none of it would run down the sides: yet, by the bare addition, even of a very fix'd and very dry body, this coagulum may, in a few hours, be reduced to a permanent liquor. But, because it is not easy to procure spirits pure enough to make this experiment, we will set down another quick way of hardening one fluid body by another. If you beat the white of an egg, till it become thin, and then shake well into it, about half its quantity of true spirit of salt, the mixture will, in a few minutes, be so coagulated, that not a drop of liquor will run from it. Another experiment, of the same nature, we have from Sir Francis Bacon, of coagulating the whites of eggs with spirit of wine; and, by shaking the two ingredients well together, I have found it succeed. He supposes, indeed, that this coagulation proceeds from the heat of the spirit of wine; but that spirit, doubtless, abounds with a piercing salt, which may very well suffice for this pur-

purpose. And we have not only produced the like effect with acid spirits, but even by a crude salt; for, by long beating the white of an egg, with a lump of alum, you may bring the greatest part of it to a white curd. So that if we will allow this coagulation, to be performed by the heat of spirit of wine, this heat must be only such, as may be ascribed to the active particles of saline bodies, which yet are commonly accounted rather cold than hot. But because I doubt how justly they are reputed so, I purposely took the serum of human blood, and endeavour'd, though in vain, to coagulate it with such spirit of wine, as would coagulate the whites of eggs; yet this serum will coagulate by a gentle heat of embers, as soon as they: which makes it suspicious, that the effect proceeded from the greater correspondence in texture, of the spirit of wine, with one of the liquors, than with the other, rather than from the heat ascribed to it, which did not at all coagulate the serum.

Thus the essential oil of aniseeds, which, in the heat of summer, remains as perfect a liquor as other chymical oils, contrary to them, during the cold of winter, coagulates into a body like camphire, and not without some degree of brittleness. We may add, that the liquor distill'd from benjamin, is subject to much more frequent vicissitudes of fluidity and firmness; for part of it, all the year long, continues in the form of a blackish oil, and the rest, according as the season of the year, or the time of the day, makes the weather cold, or hot, frequently changes its texture; sometimes appearing the same with the oil just mention'd; sometimes shooting into clear, and variously-shaped crystals; which fasten themselves to the bottom and sides of the vessel, till a warmer part of the day, or of the season, dissolves them again into a liquor. And this may also serve to confirm, that the fluidity of some bodies depends, almost wholly, upon the various agitation of their parts; for, in these instances, the parts of the aniseeds, and those of the benjamin, upon the operation, or absence of the languid heat of the air, constituted a fluid, or a consistent body.

And, as we have shewn, that two fluid bodies may be associated into a consistent one, so, on the other hand, a fluid body may, by the change of texture, be divided into two consistent ones; as in drawing the more volatile parts of salad-oil, where neither the liquor that comes over, nor the substance which remains behind in the retort, is fluid, tho' the oil which yielded them were so. But before distillation, putting to the oil a convenient quantity of common salt, and another thing or two, fit to change the texture of the branched particles whereof it consists, I then obtain'd an oil, that dropt into the receiver, in the form of a liquor, and continued fluid. I have, likewise, practis'd a way to purify the dark, muddy oil of amber, drawn *per se*, so that a large proportion of it would come over very transparent, and finely colour'd; and the liquor thus prepar'd, will swim even upon spirit of wine. My method is, to take two pounds of good brandy, one of sea-salt, half a pound of the oil, and mix them, and distil them together.

Fluidity and Firmness.

Salt-petre, by being dissolved in a sufficient quantity of common water, will seem to be lost therein; and to constitute with it, one uniform fluid substance; but, if a competent quantity of that water be exhaled, the saline particles, by re-uniting themselves, form into stable crystals of determinate figures. Which will suggest a way, whereby some bodies may become firm and solid, by the admixture of a due proportion of water, or some other liquor. For though the small parts of such fluids, being themselves in motion, are apt to communicate such an agitation to others, as fluidity principally depends on; yet an equal, or a double weight of oil of vitriol, distill'd from running mercury, will, when far the greatest part of the liquor is come over, leave a very white powder, considerably fix'd, behind it. And in preparing the best *Mercurius dulcis*, the quick-silver is so intermix'd with the salts it carries up in sublimation, that the dry and brittle body they compose, may contain much more mercury than salt. And other experiments may shew, that the mixture of a convenient liquor may cement bodies into one hard concretion, which would scarce otherwise happen: for, different qualifications may be requir'd in a body, whilst it is constituting, and when it is constituted. And though the motion of the parts that make it up, oppose the firmness of a formed body, yet it may conduce to make a firm body: for, when a great many hard corpuscles lie together, loose and incoherent, they resemble a fluid; whereas, by the mixture of a liquor, those loose corpuscles being, for a while, dissociated, and put into motion, they may, after many evolutions, apply themselves to one another, after the manner most requisite to make them touch in larger surfaces. Thus, in the burning of alabaster, if the powder, after it hath done boiling, and been sufficiently calcin'd, be well beaten some hours afterwards, and temper'd up with fair water, almost to a thin consistence, that fluid substance will, in a few minutes, begin to exchange its fluidity for firmness; so that if it were before cast into a mould, it will perfectly retain the impression thereof. And that here there is, for a while, such an agitation of the hard parts, produced upon the affusion of the water, and afterwards an exclusion of the superfluous water, appears from hence; that when any considerable quantity of burnt alabaster is temper'd with water, the mixture soon grows sensibly hot, and sometimes continues so for a pretty while: and having purposely fill'd a new half-pint vial with this liquid mixture, and stopp'd it up close, in less than half an hour it crack'd the vial in several places, and discharg'd itself, at the crevices, of about a spoonful of clear water; the remaining mixture retaining perfectly, the figure and dimensions of the vial, and growing harder than chalk. And, let me add, that some other substances may thus afford much more solid bodies, than burnt alabaster: whence it would be of good use to enquire what others are, by this means, reducible to a lasting solidity. *Fournier*, after having told us that the *Romans* made the fairest harbours in the world, by the help of a certain sand, to be met with at *Cuma*, and *Puteoli*, in the kingdom of *Naples*, which, mix'd with a third
part

part of quick-lime, acquires, in the water, the hardness of flint, subjoins, that in *Flanders*, near *Tournay*, he saw a certain sort of ashes, made with marble-lime, that was excellent for any work in the water. For, having here made a bed of great stones, they cast upon them large quantities of these ashes, instead of mortar; and the water, betwixt the stones, having temper'd them up, so petrify'd them, that, in a short time, they became as hard as marble. That the various motions, and justlings of the hard particles, conduces to their uniting into one stable concretion, seems confirm'd, by what we have observ'd in some saline liquors, especially certain parcels of spirit of hart's-horn, which, whatever were the constitution of the ambient air, remain'd fluid, some of them for many months; after which, the saline corpuscles began to shoot, at the bottom of the remaining liquor, into exquisitely figur'd crystals. For this spontaneous coagulation, happening so late, seem'd to be preceded by numerous evolutions; whence, at length, the little bodies came to turn those parts of themselves to each other, by which they might be best fasten'd together, and constitute a firm body. For this coagulation proceeded not from the evaporation of the superfluous liquor, because the glasses were carefully stopp'd; and if any thing could get away, it must have been a subtile spirit, which would only have left the remaining liquor more aqueous: and it is well known, to those who deal with such kinds of liquors, that the more aqueous they are, the less they tend to crystallize. And, having in a crystal vial, carefully kept a quantity of well-colour'd tincture of amber, made with pure spirit of wine, it remain'd fluid for a year or two; but, after two or three years more, I found several yellow lumps of amber, almost like beads, with one side flat, here and there fasten'd, partly to the bottom, and partly to the sides of the glass.

Another cause of stability in bodies, is, the admission of adventitious corpuscles into their pores: of the ways wherein this may happen, these appear to be the chief. 1. By expelling thence those voluble particles, which, by their shape, or motion, oppos'd the coalition, or disturb'd the rest of the other particles, whereof the body consisted. 2. By hindring the motion of the little bodies that compose it. And, 3. By constituting with the particles it consists of, corpuscles more unapt for motion, and fit for mutual cohesion. To these seems reducible the way of coagulating milk by runnet, whose saline particles pervading the body of that fluid, not only make a commotion in the parts of it, but fasten the branched particles thereof to one another, and, with them, constitute a body of another texture: when the weight of these curdled bodies, reducing them, by degrees, into a closer order, squeezes out the thinner liquor, which the runnet was unable to coagulate; and which, being thus sever'd from the grosser parts of the milk, may well be more fluid than the milk itself. And that there is some coalition of the particles of the runnet, with the coagulated ones of the milk, appears by the complaints made of cheeses tasting too strong of the runnet. And tho' we here ascribe the coagulation of milk, to the saline particles of runnet, yet oil of vitriol, the juices of several

Adventitious particles may conduce to firmness.

PHYSICS. ral herbs, and other things, will do the same. I have prepared a salt of the same nature with the *Sal mirabilis* of *Glauber*, which seem'd to have a power of coagulating common water; for, being dissolv'd in a convenient quantity of it, almost the whole mixture will shoot together into fine crystals, apparently of an uniform substance, and so brittle as to be pulverable; tho' the concretion may have such a proportion of water in it, that when the experiment has succeeded well, I have, from three parts of water, and but one of salt, had about four parts of crystals. I have also prepared a whitish substance, which would not only destroy the fluidity of some other liquors, but give a consistence to a large proportion even of oil of vitriol; the parts whereof are supposed to be vehemently agitated. And at the bottom of a well-stopp'd vial, I have kept a little of this powder under a considerable proportion of oil of vitriol, which appear'd consistent, without having affected the powder, whereon it had been only poured, and suffer'd to stand in the cold for a day or two. And if upon whole crystals of nitre, very well dried, and contain'd in a vial, you gently pour good oil of vitriol, till it swim about half an inch above the salt, and leave the vial cover'd with paper, at rest, in a cool place; the liquor will, if the experiment succeed, slowly settle itself about the nitre, so that the vial being inclined, it will not run out. And that in coagulating quick-silver, by the vapour of melted lead, some metalline fumes really enter the quick-silver, seems probable, from the wasting of lead by fusion, and the effects ascribed by chymists to the fume of lead upon gold. And a physician of my acquaintance, keeping some lead long in fusion, to reduce it *per se* into a calx, and holding his head often over the melting-pot, to observe the alterations of the metal, was suddenly purged several times upwards and downwards; which both he and I ascribed to the metalline exhalations. And tho' I suspected the congelation might proceed from the loss of some subtiler substance, that formerly agitated, but after deserted the mercurial corpuscles; yet that the concretion of the quick-silver might be effected by some benumbing vapour of the lead, seems confirm'd by an observation of that great geometrician, *Dr. Wallis*, and others at *Oxford*; who in making the experiment under consideration, found, that upon the first fusion of the lead, the quick-silver being tied up in a rag, and, before it grew too cool, immers'd therein, was very well coagulated by it; but when they came to melt it the second time, and put other quick-silver into it, the experiment would not succeed: which seems to prove, that there is in lead a coagulating steam, or spirit; but in so small a proportion, that it almost totally dislodges, or spends itself, upon the first opportunity it meets with, of passing into quick-silver. Pouring some common sallad-oil upon *Aqua fortis*, it at first floated together on the top of it, but after some hours, had its texture so chang'd, by the ascending steams, that it was turn'd into a white consistent body, resembling butter. The like we have perform'd with expressed oil of sweet almonds. And some times pouring off the same *Aqua fortis*, or spirit of nitre, wherewith I had coagulated oil-olive, from the butter-like substance, I have cast camphire into

into it, which, without heat, was thereby reduc'd to an oil, retaining a distinct surface from the menstruum whereon it floated; so that the same menstruum, unassisted by fire, turn'd a brittle body into a liquor, and *vice versa*; for common oil suffer'd to float long enough upon it, will be brittle. And this brittle substance, seem'd to receive a more durable alteration from the menstruum, than we expected: for, when melted with heat, it would, upon cooling, become again consistent; and I could not reduce it to a liquor, by mixing it with oil of tartar *per deliquium*; which has a great power to mortify acid spirits, such as *Aqua fortis*, and spirit of nitre. The last way whereby external corpuscles, entering into a body, may give it a stable consistence, is, by causing such a commotion in the parts of it, as may make them apply themselves one to another, in a greater surface, or otherwise complicate and dispose them after the manner requisite to make them stick together. This way of rendring bodies consistent, is seldom or never employ'd by nature, without the concurrence of some of the other means already mention'd: but we have distinguish'd it from the two last, because, in them, we suppose some of the adventitious corpuscles to be stopp'd in the body, to whose firmness they conduce; but here we suppose, that without materially concurring to constitute the body they work on, they only agitate, and variously move the particles it consists of; so that the parts, which formerly either mov'd separately, or adher'd together but loosely, are now reduced to a closer order, or more implicated texture, and thereby more firmly connected to one another. That the bare disposition of the parts of a body, with regard to each other, without any addition of foreign matter, will greatly conduce to stability, we may see both in some examples formerly mention'd, and in osier wands, which, when lying loosely in a heap together, may each of them very easily be dissociated from the rest; but, when they are breaded into a basket, they cohere so strongly, that if you take up any one of them, you raise all the rest. We might add those many obvious instances, wherein, by the bare texture of the slender hairs, or threads whereof wool or silk consists; cloth, stockings, and many other durable garments, are made. We may, also, observe the force of bare motion, in altering the texture, and, thereby, the consistence of bodies in the common way of churning: for there the external impulse, makes a great commotion in the parts of the cream; whence the more branched corpuscles, meeting with one another, are intangled, and thereby separated from the rest: and, after many occurrences, all these parts are, at length, fasten'd to one another; and excluding those of the thinner fluid, which seem not so conveniently shaped for mutual cohesion, constitute butter; which is made yet more consistent, or compact, by being compress'd, as the parts thereby reduced into a closer order, squeeze out the liquor which was intercepted amongst them. It will, perhaps, be thought more strange, that a fluid body, nay, a distill'd liquor, which is very volatile, and passes for simple, and homogeneous, should, by motion, without the mixture of any new matter, be made coherent; yet, even the chymical oil of turpentine, may, in a great measure, if not wholly, be coagulated without

PHYSICS. without addition. A very expert chymist shew'd me, in a receiver, some oil of turpentine, which he had often distill'd over *per se*, very much coagulated into a whitish and consistent body; affirming, that he had, sometimes, by frequent distillations, without addition, obtain'd from clear oil of turpentine, a far greater proportion of such a stable substance; whose consistence, whether it should be ascribed to the fire's breaking the oily corpuscles into parts more fit for mutual cohesion; or whether it proceed from a new texture of the same corpuscles, happening from those various evolutions, to be disposed after such a manner, as to complicate, or otherwise connect them, I need not now enquire: it is sufficient, that we hence see how much even motion, without the addition of any sensible substance, may, in some cases, conduce to firmness. I have observ'd, that oil of wax, distill'd in a retort, with a proper addition, tho' at first it chiefly came over in the form of a butter, yet, by standing in a cool place, and in cool weather, it would gradually resolve into a transparent oil.

Firmness may be the result of a particular texture.

But what if fluidity and stability depend so much upon the texture of parts, that by the change of that texture, the same parts may be made permanently to constitute either a fluid, or a dry body? An instance of this is afforded us by quick-silver; for, if some ounces of that fluid mineral, be put into a convenient glass-vessel, and that vessel be first exactly stopp'd, and kept for six, eight, or ten weeks, in a sand furnace, whose heat may be strong and constant, the corpuscles that constitute it, will, after innumerable revolutions, be so connected to one another, that instead of a fluid body, they will appear in the form of a red powder, which chymists call precipitate *per se*. But to do this more expeditiously, take half a pound, or a pound of quick-silver, and, with a strong fire, distil it out of a glass retort; and, for the most part, there will remain in the bottom, and about the sides of the vessel, a little red powder, which seems to be nothing but part of the fluid body turn'd into a dry one, in eight or ten hours time. After what manner the fire produces so odd a change in the quick-silver, I presume not to know. It is true, that tho' the corpuscles of liquors touch one another but in part of their superficies, yet they all of them seem to have some degree of viscosity, slight complication, or adhesion of parts; as appears by their being so easily reduced into those thin membranes, or films, which we call bubbles: so that not only spirit of wine will afford them, but even quick-silver, notwithstanding its ponderosity, being suffer'd to fall in a slender stream, into a vessel almost full of the same mineral, yields numerous and large bubbles, though they are not lasting. Hence it might be imagin'd, that in this operation, some such change is made in the quick-silver, as we formerly observ'd in the white of an egg; when, a new disposition of its parts, caused either by heat, or concussion, makes it a kind of stable body: or else it may be argued, that there is a variety of parts in quick-silver, from the great variety of its effects upon other bodies; and that by the frequent evolutions, which the fire makes of those parts among themselves, they come, at length, to be

so applied to one another, as either to lock into each other, or slip upon one another's surfaces, so that as much of their surfaces immediately touch, as is requisite to make them cohere. These conjectures, and many others, may be proposed, but, I fear, all of them will not solve the phenomenon. Nor were we much instructed, from viewing our mercurial precipitate in an excellent microscope: we hence only discover'd, that the red powder had in it many corpuscles of various other colours; and that the little grains had no determinate shape, but appear'd like slender fragments of red coral. And having put some small dust of a shining precipitate of gold and mercury, into the same glass, all we could discern was, that the little grains of this, differ'd from those of the other; being so transparent throughout, that any one would have thought he beheld the best sort of those precious stones call'd granats. But tho' we pretend not to shew, how the new texture is produced in the quick-silver, yet to make it still more evident, that its change of consistence proceeds from its change of texture, we will add, that having a desire to try whether our powder could not be made fluid again, I procur'd some precipitate *per se*; which being weigh'd, and put into a convenient glass, was carefully urged with a naked fire; and, at length, it rose, by degrees, in fumes, which settled in the neck of the glass, in many drops of running mercury; all which, being collected into one, we found that there wanted but about a sixth or seventh part of what we had put in; and, perhaps, we had not wanted that, only the vehemence of the fire melted the glass, which took up so much of the powder, as made a great shew thro' it, after we had remov'd what was fused, from the fire. Having half an ounce of a certain mercury, which I took for that of lead, I found I could, barely by shaking it long together, reduce it to a black powder; in which form it would continue as long as I pleas'd: and barely by dextrously rubbing it in a marble mortar, I could immediately reduce it to a running mercury again; which quick passage from one to another, being made without the help of fire, or without adding, or taking away any visible substance, shews how greatly motion and rest, and the texture of the component parts of matter thence resulting, may contribute to fluidity and firmness. Hence we learn what to think of the doctrine of some modern philosophers, who teach, that a fluid body is always divisible into bodies equally fluid, as quantity is into quantities; as if the particles of fluid bodies must also be fluid themselves: for, it appears, that quick-silver, and some other actually fluid bodies, greatly consist of of hard corpuscles, since, by the change of their texture, they may be depriv'd of their fluidity, and become stable. We see, also, that the stiff and solid particles of salts, dissolved in common water, and of silver dissolv'd in *Aqua fortis*, being, by those liquors, sufficiently dissociated, and separately agitated, with them constitute fluid bodies. And, by putting together, in a glass retort, one part of quick-silver, and four of common oil of vitriol, and distilling them in a sand furnace, with a strong fire, there remain'd in the bottom of the vessel, a ponderous calx, so far from fluid, that it was but in part dissoluble in water. And what seems to prove, that,

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PHYSICS.

in the very liquid oil of vitriol, tho' a distill'd liquor, the saline corpuscles which chiefly compose it, retain their stiffness; by steeping our calx in fair water, we could separate from it a considerable quantity of particles, which, upon the evaporation of the water, coagulated into numerous saline and brittle bodies: and that these proceeded rather from the menstruum than the metal, we were induced to think, by observing, that the dry calx, before any water was poured on it, weigh'd a great deal more than the quick-silver, when it was put in; and the oil of vitriol that was abstracted, a great deal less than before it was committed to distillation. Nay, I observed in a glass, where I kept a quantity of oil of vitriol, that there spontaneously fasten'd themselves to the sides, little saline crystals, which I found hard and brittle; but when I had expos'd them to the air, they presently resumed a fluid form, and appear'd to be oil of vitriol. In the observation also, lately mention'd, of the spontaneous coagulation of spirit of hart's-horn, it seems evident, that bodies, which are all, or most of them, hard, and appear so when they are commodiously connected to each other, may yet constitute a fluid body, when reduced to a sufficient smallness, and put into a convenient motion. And, indeed, if the least particles of fluid bodies were not endowed with their determinate bigness and shapes, but such fluid bodies could be always divided into particles also fluid; how comes it to pass, that some liquors cannot pierce into, or moisten some bodies which are easily pervious to other liquors? For if the particles of the excluded liquor were of necessity always divisible into fluid ones, there seems no reason why they should not be subdivided into such very small ones, that no pores can be supposed little, or oddly enough figured, to keep them out. It is true, the matter whereof fluid bodies consist, is capable of being indefinitely divided; and it may be granted too, that the smaller the parts into which a body is divided, the more easily they may, *ceteris paribus*, be put in motion: but this divisibility of a fluid body into perpetually less parts, belongs not to it properly, as a fluid, but as it is a body; such divisibility, if supposed true, being a primary property of matter itself, and belonging as well to those portions of it which are hard, as to those which are fluid. And tho' it were admitted, that such an endless division might be mentally made; yet it would remain a question, whether nature, in fact, divides bodies so far: however, it is not only requisite to the constitution of a fluid body, that the parts of it be small enough, but that they be also actually moved. For we lately observed, that the dust of alabaster, put into motion, resembled a fluid body; and immediately ceased to be fluid, when it ceased to be agitated; whereas the particles of water, as minute and apt as they are to constitute a fluid substance, do yet make that hard and brittle body we call ice, when those little particles, upon what account soever, are reduced to a state of rest.

The chymical
notion of stability,
&c. examin'd.

From what is here deliver'd, we may also be assist'd to judge of the doctrine of the chymists, who teach, that in all bodies, coagulation, stability, hardness, and brittleness, depend upon salt; for tho' what has been said of the curdling of milk by saline liquors, and the hardness obvious in
salts

salts themselves, may keep us from denying, that the saline principle is very powerful in the coagulation of some bodies, that is, produces much firmness, or even brittleness, in many of the concretes wherein it is predominant; yet this hardening power seems not to proceed from any peculiar property to coagulate other bodies, or make them compact; but from the shape and motion of its corpuscles, which, it seems, are more fitted by nature, than those of many other concretes, to insinuate themselves into the pores of bodies, and fasten their particles to themselves, and to one another; as when many pieces of paper are kept from scattering, by a wire run thro' them. But whenever there is in the constituent parts of a body, a sufficient fitness and disposition to adhere firmly to one another, nature may of those parts compose a stable body, whether they abound in salt, or no; it not being so much upon chymical principles, or even upon the predominancy of any one ingredient, as upon the shape and motion of the component parts of bodies, that their fluidity and firmness depend. I will not here urge that salts are generally reducible by an easy mixture with water into the form of liquors; nor that sea-salt, salt of tartar, and many other sorts of salts, will, of themselves, even in the air, assume the form of fluids; nor yet will I press the example of coral, which is confidently affirmed to be soft, whilst it remains in the salt water, and to grow hard when taken out of it: but I shall rather demand, what salt can be made appear to pass out of the body of melted lead into that of quick-silver, to perform in it the coagulation above-mentioned? What accession of salt is to be observed, when running mercury is precipitated *per se* into a powder? And how will it be proved, that when, in a well-stopped glass, the whole body of water is, in frosty nights, turned into firm ice by the cold of the air, that coagulation is performed by salt: for chymists have not yet made it appear, that either salts, or even the distilled spirits of them, can penetrate, without a kind of prodigy, the narrow pores of unheated glass? It is usually observed in eggs, that tho' at their being first laid, the shells are soft, yet they soon after grow hard and brittle; yet it appears not how the saline ingredient is increased, to effect this speedy induration: and tho' the coldness of the outward air, and its imbibing some of the moist parts of the soft shell, may concur herein; yet there are many observations of egg-shells, found hard in the hen. And I myself have found several eggs, at one time, in the body of the same hen, which were each of them furnished with a compleat and brittle shell. I farther demand, what quantity of salt can pierce the hard shell, and close-wrought membrane, that both lines it, and involves the egg, especially since eggs may be hatched by a temperate external heat without the hen? Yet we may here observe, that the same internal substance of the egg, which at first was fluid, is, upon the exclusion of the chick, turned, almost wholly, into consistent bodies, some of them tough, as the membranes and gristles of the bird; some of them harder, and almost brittle, as its bones and beak; and all this without the accession of new salt. It would be difficult for chymists to prove, that diamonds and rubies contain salt: and it may be also questioned, whether

PHYSICS. the blood of animals, when it is freest from serum, does not, tho' a liquor, as much abound with salt, as their skins or flesh.

And since it is with chymists that I now argue, I farther demand of them, whence it happens that one grain of the powder of projection can turn a whole pound of mercury into true gold or silver; and, consequently, change a very fluid body into a very firm one; tho' the proportion of salt employ'd, would not amount to the six or seven thousandth part of the liquor. To this I shall add, what *Helmont* relates upon his own experience, and that of *Raymond Lully*, concerning his alkahest, that, being abstracted from common quick-silver, it, in a quarter of an hour, coagulates it, yet leaves nothing of itself with the mercury on which it works. I remember also, that a physician of great veracity told me, that at the Duke of *Holfstein's* he took notice of a glass of spirit of urine, which in warm weather remained in the form of a liquor, but was in cold weather totally coagulated into crystalline salt; in the preparation of which, he said, the Duke caused spirit of urine, exceeding rich in volatile salt, to be very often distill'd; after every distillation uniting all that came over in a liquid, with that which remain'd in a saline form, till by very frequent cohobations, all the parts of the urinous substance were brought to the coalition above-mentioned.

And on this occasion, we will annex a few other particulars, tending as well to render the chymical hypothesis doubtful, as to confirm our own. And first, in the art of making sugar, very great care is taken, that nothing acid fall into the caldrons, (especially the juice of lemons) wherein the juice of the sugar-cane is to coagulate: for tho' acidity be generally by the chymists ascribed to salt, yet these saline bodies are here so far from promoting the coagulation of the saccharine syrup, that they would utterly prevent it. To the authorities of *Pisib*, and others, for this, I might add what has been confirmed to me by persons who pretend more than ordinary knowledge in the art; but all agree, that the juice squeezed out of the sugar-canes is first boiled, and purified in vast vessels of copper or brass, whence it is afterwards convey'd to be farther purified and coagulated in smaller; and that whilst it is in the former, they pour upon it some very strong lixivium to facilitate the separation of its feculencies; as in the small ones, it is usual to pour a little oil or butter upon the boiling juice to keep the syrup from boiling over. They farther declare, that if the oil were added to the liquor in the larger vessels wherein it is first clarified, or the lixivium put to it in the smaller, in either case, it is absolutely impossible to make sugar. So greatly do the fluidity and firmness of bodies depend upon their texture, how much soever the chymists would have them depend upon salt.

To this borrowed observation, we will add two or three experiments of our own, made on purpose to give light into this matter. First then, we prepared a liquor as saline as *Aqua fortis*, and yet when we laid fragments of solid harts-horn of several sizes to sleep in it, the menstruum was so far from hardening, that it would pierce into and soften them; so that in about two or three days, it reduced them to a kind of white mucilaginous substance. We took, also, good salt of tartar, and poured on it spirit of vinegar,

negar, as long as the affusion would produce any ebullition; then we distill'd off the liquor, which came over almost insipid; the saline parts which make the spirit of vinegar so sharp, being retained by the salt of tartar: upon the remaining dry mixture, we poured fresh spirit of vinegar, as long as any hissing ensued, and afterwards abstracted the aqueous parts of this parcel of liquor also; and so we proceeded, till having sufficiently impregnated the fixed salt with the saline parts of the distilled vinegar, we obtained a mixture, which, tho' wholly consisting of salts, required not the heat of the fire to turn it into a liquor. Lastly, we took common oil of vitriol, and cast into it several little pieces of camphire, which floating upon it, were by degrees, in some hours time, wholly reduced into a reddish oil, which appeared together upon the top of the other liquor: then, having formerly found, that oil of vitriol would easily mix with common oil, we tried also, by shaking the saline and camphorate liquors together, to unite them, and easily confounded them into one high-coloured liquor, which seemed very uniform, and continued so for many hours; then we added to this mixture three or four times as much fair water, and the camphire immediately became a white consistent body again, and by degrees settled at the top of the liquor: where we may observe, that the camphire is not made hard, but fluid, by mixing with the saline corpuscles of oil of vitriol; and that it exchanges its fluidity for firmness upon the affusion of insipid water.

And thus much may suffice to have said of the stability of bodies from salt. As for the hardness and brittleness which the chymists also ascribe to the same principle, how much they may be increased or diminished, without the addition or decrease of the saline ingredient, appears in the experiment of tempering a slender piece of steel: for when this hath been sufficiently heated, you may, by plunging it red-hot into fair water, which is more likely to dissolve than increase its salt, make it both very hard and very brittle; but by too leisurely cooling in the air, it will become much less hard, and more tough: and if, after having quenched it in cold water, you again heat it, till it have attained a deep blue, it will become soft, and very flexible; and that not from any waste made of the saline ingredient by the fire: for if this softned steel be again heated red-hot, and suddenly cooled, whether in water, or otherwise, it will regain both hardness and brittleness. And that by procuring a closer order, and more immediate contact of the parts of a body, we may, without increasing the salt, increase the hardness of it, is also obvious from compressing snow, as was formerly observed.

I know that several philosophers, entirely ascribe the induration, and especially the petrification of bodies, to a secret internal principle, by some of them called a form, and by others a petrifying spirit, lurking commonly in some liquid vehicle; and from considering several crystalline bodies, and regularly-shaped stones and other minerals, which I have seen and known to be dug out of the earth, I am forward to grant, that it is a plastic principle implanted by the wise creator in certain parcels of matter, which produces in such concretions, as well the hard consistence, as the determinate figure. But the difficulty consists in conceiving how that internal principle produces

PHYSICS. its effects ; which these writers not pretending intelligibly to explain, we thought proper to survey some of the principal ways, by which nature seems to make bodies firm and stable; whence we may be assisted to judge whether it is necessary to have recourse to a plastic principle, or petrifying spirit, in the hardening of such bodies, whose curious and determinate textures argue their having been fashioned by some one formative power, or by several seminal principles convened together. And because hardness is a high degree of firmness, we shall shew by some examples, how small an external operation may, without any apparent adventitious salt, render a soft body hard, and even brittle, when there appears no other change to be made, than in the texture or disposition of its component particles.

It is a tradition that coral grows soft at the bottom of the sea ; but when it is brought up into the open air, tho' it retains its bulk and figure, yet it then hardens into a stony concretion; according to that of *Ovid*,

*Sic & corallium quo primum contigit auras
Tempore, durefcit ; mollis fuit herba sub undis.*

Now as to the truth of this tradition, *Gassendus*, in the life of *Piereskus*, has this passage concerning that gentleman's fishing for coral near *Toulon*. "The plants which were plucked up, appeared neither red nor beautiful, till their bark was taken off; in some parts they were soft, and would give way to the hand, as towards the tops, which being broken and squeezed, they yielded milk like that of figs." *Fournier* likewise, after having particularly described the way of fishing for coral near *Toulon*, adds, "these plants are neither red nor smooth when drawn out of the water, till their rind has been taken off; nay, they are soft, and being squeezed between the fingers, throw out a kind of milk resembling that of figs: and when the pressure ceases, the small holes or pores, that harboured the milk, are visible*." The credibility of these accounts has been confirmed to me by a physician, who, in his return from the *East-Indies*, having made some stay on the island of *Mehila*, near that of *Madagascar*, where white coral is reported to grow in plenty, assured me, he had often gathered coral upon the sand of that island, and found it, when first taken up, exceeding white, and (to use his own expression) as soft as an onion; adding, that tho' it would soon grow hard in the air, yet if it be not gathered at a seasonable time of the year, it will not keep long, but either crumble away, or otherwise decay. And *Piso*, in his natural history of *Brazil*, speaking of

* *M. Geoffroy* tells us, that Count *Marfigli* satisfied himself, coral was a plant, by placing it, when newly fished up, in sea-water; where, after some time, he perceived that the little red tubercles upon the surface of its bark gradually expanded, and, at length, appeared in the form of white flowers, star-fashioned, with eight points, and a small calix divided into

eight parts: but taking the branches out of the water, these flowers presently closed up, and formed themselves into red tubercles again, which being squeezed, afforded a milky juice. Putting the branches again into sea-water, these tubercles flowered again, and continued thus for eight or ten days. *Memoir. de l'Acad. An.* 1708. p. 130.

places

places upon that coast, where many stony plants, some like little trees, some otherwise figured, may be seen in clear weather growing at the bottom of the sea, tells us, that if they are plucked up from the bottom, they presently, by being exposed to the sun upon the shore, become exceeding hard, dry, and white. And *Scaliger* tells us, upon his own knowledge, of a shining matter voided by urine, which in the air coagulated into a firm substance like glass. It is, also, affirmed of amber, that it hardens in the air after being dragged out of the sea; which seems the more credible, because I have seen a whole spider perfectly inclosed in a piece of hard and transparent yellow amber. It is not impossible, that the contact of the external air may put the parts of such small bodies into a new motion, whereby some voluble corpuscles, which hinder their reciprocal adhesion, may be excluded, and the particles themselves press'd, or otherwise disposed into a closer order: and we find, that some oil-colours, after they are brought to their due temper, may be preserved very long in the same degree of softness, if they, and the shells that contain them, be kept all the while under water; tho' in the air, they would quickly change their texture, and become dry and hard. But tho' in the last example, the removal of a body out of the water into the air, seems manifestly to contribute towards its growing hard; yet it is not so easy to determine, what share the air hath in effecting such indurations: for *Gassendus* relates of *Piereskus*, that it being his custom in the summer time to wash himself in one of the lesser streams of the *Rhofne*, he there once felt the ground, which he used to find even and soft, grown hard with little round balls, like hard boiled eggs without their shells; some of which he took up, carried home, and in a few days after, returning to the river, he found those little balls or lumps turned into perfect pebble-stones; which he observed likewise beset those which he had carried away, and laid up. I have known two or three spoonfuls of burnt alabaster, mix'd up thin with water, in a short time coagulate at the bottom of a vessel full of water, into a hard lump, notwithstanding the water that surrounded it; which, it seems, by the texture of the mass, was kept out of its pores, as it is out of those of the oils of cinnamon and cloves, which, tho' fluid bodies, that will sink in water, suffer not its particles to insinuate themselves between theirs: and artificers observe, that the coagulating property of burnt alabaster will be very much impaired or lost, if the powder be kept too long, especially if in the open air, before it is made use of; and when it hath been once temper'd with water, and suffer'd to grow hard, they tell me, they cannot, by any burning or powdering of it again, make it serviceable for their purpose as before: so much doth the coagulation of these powders, mixed with water, seem to depend upon their texture, and other mechanical qualities. I remember also, that tho' the bones found in the hearts of deer, so extolled by physicians, do, in the air, acquire a hard consistence; yet having consider'd one of them in the heart of a deer newly kill'd, I found it there of a cartilaginous softness and flexibility. And I have often doubted, whether not only consistent bodies, but some of the most solid, may not have been fluid in the form either of steams

or

PHYSICS.

or liquors, before their coalition into stones or other mineral bodies. There are many who think, that stones, marcasites, and such other durable bodies, were made together at the creation; and will not admit, that such concretions can now be generated: tho' it would not be difficult to shew, that such parcels of matter are now to be met with in the form of stones, as did not before appear under that form; but whilst it was divided into minute parts, either was itself some fluid body, or at least did, as a material part, concur to constitute one that was so. I have seen a flat stone, in which was most lively ingraven the figure of a small fish, with all the fins, scales, &c. which was affirmed to have been inclosed in the body of that stone, and to have been accidentally discovered, when the stone, chancing to receive a blow upon its edge, split asunder. A servant of mine, in the country, inform'd me, that whilst he caused one of my walls to be repaired, the mason breaking a stone to use about the building, found in it a piece of wood, which seem'd part of the branch of some tree. And this appears to me a more cogent proof of the increase of stones, than several others, on which eminent naturalists rely.

And unless we will suppose, there were, from the beginning, made together with, or in the midst of great masses of one kind of mineral, little parcels of another, of a quite different sort, either whole quarries of stone, or heavy and shining minerals, or both, may have been fluid bodies. The observation whereon I ground this conjecture, is, not only that we have met with in lead-ore, and also in *minera antimonii*, parcels of a white stone, or spar, surrounded with a metalline body; but chiefly, that I have, with my own hands, taken a hard, ponderous, shining mineral, like a marcasite, of the shape of a pear, and of about the bigness of a walnut, out of the very body of a stone which environ'd it on all sides; and this I took, not out of a small and loose stone, but a large one, dug for statues. And one of those who wrought upon it, told me, that in fashioning it into statues, they found it contain more minerals. And a statuary, having taken much pains to saw asunder a very large stone, when he came to the middle of it, found he could go no farther; the stone being broken, he perceived, that what so obstinately resisted his saws, was a round marcasite, which he brought me; but I caused him, for my satisfaction, to bring also that part of the stone, wherein the marcasite lay, and by comparing them together, I discern'd, that as much of the stone, as was contiguous to the marcasite, had a kind of rust about it, and fitted the marcasite so close, as if either that had been formerly liquid, and afterwards, as it were, moulded in its receptacle, or the stone had been originally of some soft or fluid matter, which exactly accommodated itself to the shape of the other body; or, lastly, as if both the matter of the stone, and that of the marcasite, had been at once fluids; each preserving its own surface distinct, till one of them first growing hard, the other, as being yet of a more-yielding consistence, accommodated itself to the figure of the former.

But the most eminent instances, to manifest how much the fluidity and firmness of bodies depend upon the texture of their parts, are afforded by those

those waters, which, being permitted to rest a-while, cease to be fluid, and coagulate into stone. An ingenious man, lately going to visit some lead-mines, wherein he had a share, found in the mountain, where they were hid, a cave, from whose arched roof, there drop'd down a petrescent liquor, which often congeal'd, before it could fall to the ground, and by the apposition of like matter, increased so much, as to hang from the roof, like icicles, from the sides of a house; and of these he gathered, and brought me several, which are perfect stones, hard and brittle, eight or ten inches long, and proportionably thick. Another friend of mine, being lately in the cave, so famous for its petrifying liquor, in *France*, and observing some drops of water to congeal into stone, whilst he stood by, took them away with him, and sent them to me. And we shall scarce deny, that an external agent, of an almost insensible bulk, may turn animal bodies into stones, by introducing a new texture into their parts, if, with some modern writers, we credit *Aventinus*, who, in his *Bavarian* history, records, that at a certain time and place, above forty men and women, with their cattle, killed by an earthquake, had their bodies, by a terrene spirit, turned into statues; which, he saith, were seen by the chancellor of *Austria* and himself. And we meet with some relations of this nature in other authors, which, if allow'd, will much confirm our doctrine; for in these strange petrifications, the hardening of the bodies seems to be effected principally, as in the induration of the fluid substances of an egg into a chick, by altering the disposition of their parts; since the petrifying steam cannot be supposed to have any such considerable proportion in bulk, to the body changed by it, as to effect this change chiefly as an ingredient. We may add, that *Pamphilio Piacentino* is, by another author, quoted for an unparallel'd account of a woman in *Venice*, who, after having eaten an apple, supposed to have been poison'd, was seized with hideous tortures, and dying in the space of twenty-fours after, was turned into exceeding hard stone. But lest we should seem to build upon the observations of others, which cannot be now brought to strict examination, we will produce a practicable experiment of our own.

Take then two ounces of quick-silver, two ounces and a half of the best verdigrease, about half an ounce, or an ounce, of common salt, a pint, or pound, of white-wine vinegar, and as much fair water; incorporate the verdigrease, quick-silver, and the salt, very well, and put the mixture, with a little of the vinegar and water, into a new pan, and fry it over the fire for several hours, keeping it continually stirred, and putting in more vinegar and water from time to time, as that already put in consumes: then take out the mixture, and, in several clean waters, wash it carefully from the adhering salts, and dry up the aqueous moisture with a clean linen-cloth; whereby you will have a bright amalgam, almost like quick-silver. Now, tho' this dried mixture be, long after it is perfectly cold, not only soft, but so near to fluid, that I have cast it into moulds, and made imboss'd images of it; yet by laying it a few hours in the air, which seemed less cold than itself, it has acquired such a hardness, that being thrown against the floor,

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PHYSICS. it would rebound; and proved brittle, like over-harden'd steel: but in this example, the induration of the amalgam appears not to proceed from an innate and inward principle, but from the new texture, resulting from the coalition of the mixed ingredients, which make up the amalgam; whose parts, being variously moved by means of the fire, and native propensity of the mercurial corpuscles to motion, were by degrees so disposed, that as before, touching one another but loosely, it was easy to thrust some of them towards the middle of the body, without stirring much of the mass; by this change of texture, the particles are brought to touch one another more closely, and in greater portions of their surface, and to be so complicated among themselves, that you cannot endeavour to thrust one of them out of its place, but its motion shall be resisted by many others, whereto it is so fasten'd, that part of the mass cannot be moved, without either moving the whole, or manifestly breaking it off from thence, and thereby destroying the continuity and union of the body. And that several of the ingredients did concur to constitute the soft mass, which afterwards grew so hard, appears from hence, that the quick-silver was not so barely changed in texture, as that formerly said to have been coagulated by the mere fume of lead, but concealed in itself a great number of metalline corpuscles, besides others; for we separated from the amalgam, merely by the force of fire, a large quantity of true and perfect copper. That the salts also were both ingredients of the mass, and might have some operation upon the other particles, seems probable: for having purposely exposed some of this mass for a while to a moist air, we found, that the formerly invisible particles of salt, which had so insinuated themselves into the amalgam, that all the water, wherein it was washed, did not separate them from it, had so wrought upon the external metalline particles, that they had, in many parts of the surface of the mass, turned themselves with it into a kind of verdigrease, which seemed almost to hide the surface of the concretion. And that in the more inward parts of a much harder body than our yielding amalgam, where cupreous particles abound, saline corpuscles may have a great effect, appears from certain sorts of minerals to be found in some parts of *England*, and elsewhere, under the form of stones, of which they make vitriol; for these abounding with vitriolate, that is, both saline and metalline particles, will, after they are taken out of the ground, and laid in the open air, by the working of the inward salt, some sooner, and some later, swell and burst asunder: which could hardly happen, without a great change made in the internal disposition of the parts of such stony concretions. And having laid a mineral, of kin to these stones, for some time in the air, tho' but in a chamber, I found its surface powdered with little grains of vitriol, as both their colour and their taste informed me. Now whether we suppose or no, that the fire put the parts of the amalgam into a lasting agitation; yet the mass being almost fluid, after it was taken from the fire, its parts may, according to our notion of fluidity, be well supposed to have some kind of motion among themselves; and it will not be denied, that the fire might concur, with other things, to make that motion convenient to cause the parts

parts to fasten themselves to one another; for that the motion, wherein a soft, and almost fluid body, is once put, may possibly tend to harden it, long after that motion seems to be extinct, appears probable, from what has been affirm'd to me by eminent and experienced masons, that the best sort of lime, made into mortar, will not have attain'd its utmost compactness, till within twenty-five, or thirty years, after it has been employed in building: and this is given me as one of the reasons, why, in the demolishing of antient fabrics, it is sometimes more easy to break the stone, than the mortar. And, lastly, as to the texture resulting from the blended ingredients of our amalgam; having changed the proportion of the quick-silver to the verdigrease, we found that it coagulated much more slowly, and when coagulated, was much softer, than when we used the quantities above set down.

I shall add an instance of a natural induration, which, compared with our artificial one, may shew how nature and art have sometimes resembling operations in rendring bodies solid.

F. Pierre Pelleprat, who was lately sent, with some other Jesuits, to South-America, has this passage, in the short relation he makes of the American continent. "It is," saith he, "worthy of observation, that near the mouth of the great river of the *Amazons*, there is found a kind of green clay, which is so soft, as long as it remains in the water, that one may print on it all kinds of figures, and give it what shape one pleases; but when it is exposed to the air, it hardens to such a degree, that diamonds are not much harder than the stones it affords." I have," adds he, "seen hatchets made of this clay, which the savages employ'd to cut wood with, when they had not the use of ours." In the last place, I shall give a remarkable experiment, to shew how much fluidity and firmness may depend upon the texture, motion, or rest of the insensible parts of bodies. Make a solution of coral, with good spirit of vinegar, so strong, that when filtered and cooled, it will, after some time, begin to have a sediment; gently pour off the clear, when the experiment is to be made, and add thereto a convenient proportion of highly rectified spirit of wine; which if slowly and warily poured on, may be made to swim upon it as a distinct liquor: but if by a few shakes you mix them together, they will presently concrete into a substance, of which, when the experiment is well made, not one drop will fall to the ground, upon turning the containing wide-mouth'd glass, and holding it upside down. But if you add a convenient quantity of spirit of nitre to the mixture, and stir it briskly therewith, the whole will in a few minutes be reduced to a transparent liquor*.

But

* Nothing can more conduce to explain the nature of fluidity and firmness, than the following passage of Sir Is. Newton. "The parts of all homogeneal bodies," says

PHYSICS.

Mr. Hobbs's
doctrine of fluidity
and firmness examin'd.

But I must not conclude this discourse without observing, that when Mr. Hobbs disputes against my opinion of fluidity, he very much mistakes it; as may appear by this part of his physical dialogue. "They generally distinguish the nature of a fluid, from that which is not fluid, by the greatness of the parts of which any body consists: wherefore they do not only look upon air, water, and liquors, but upon ashes also, and dust, as fluid bodies; and deny not that fluids may be made of solids; for they digest not the notion of infinite divisibility: infinite
"divi-

"says he," which fully touch one another, stick together very strongly. And for explaining how this may be, some have invented hooked atoms, which is begging the question; and others tell us, that bodies are glew'd together by rest, that is, by an occult quality, or rather by nothing: and others, that they stick together by conspiring motions, that is, by relative rest among themselves. I had rather infer from their cohesion, that their particles attract one another by some force, which, in immediate contact, is exceeding strong, at small distances performs many chymical operations, and reaches not far from the particles with any sensible effect.—All bodies seem to be composed of hard particles—even the rays of light seem to be hard bodies—and therefore hardness may be reckon'd the property of all uncompounded matter—for all bodies, so far as experience reaches, are either hard, or may be harden'd.—Now if compound bodies are so very hard, as we find some of them to be, and yet are very porous, and consist of parts which are only laid together, the simple particles, which are void of pores, and were never yet divided, must be much harder. For such hard particles being heaped up together, can scarce touch one another in more than a few points, and therefore must be separable by much less force than is requisite to break a solid particle, where parts touch in all the space between them, without any pores or interstices to weaken their cohesion. And how such very hard particles, which are only laid together, and touch only in a few points, can

"stick together, and that so firmly as they do, without the assistance of something which causes them to be attracted or pressed towards one another, is very difficult to conceive.—Now the smallest particles of matter may cohere by the strongest attractions, and compose bigger particles of weaker virtue; and many of these may cohere, and compose bigger particles, whose virtue is still weaker, and so on for divers successions, till the progression end in the biggest particles, on which the operations in chymistry, and the colours of natural bodies, depend; and which, by cohering, compose bodies of a sensible magnitude." *Newton. Optic. p. 364—370.* From hence Dr. Clarke, treading in the steps of Sir Isaac, thus argues. "The primitive and most minute particles of matter cohere among one another, not by rest, but by mutual attraction; and of these solid and perfectly hard particles, 'tis plain, that all bodies, both fluid and solid, are equally composed. We are then to enquire what must be the figure and composition of the larger particles, in order to compose both fluids and solids. Now, 1. when the particles of a body are so put together, that they touch one another in large surfaces, that body, the mutual attraction of its parts being very strong, will be exceeding hard. And, 2. as those parts afterwards only touch, or are also interwoven among themselves, so the body will be more or less brittle, and melt with a greater or less heat; whence proceeds ice, wax, glass, metals, bones, wood, &c. 3. The bodies, whose particles touch in smaller surfaces, and consequently
"are

“division cannot be conceived, say they, but infinite divisibility easily
 “may: But I do not understand the distinction of fluids and not fluids,
 “which they take from magnitude; could I relish this, I must say, that
 “the ruins of shatter’d stones, which lie in *Paul’s* church-yard, were
 “fluid. But if those ruins cannot be call’d fluid, because the stones are
 “too big, tell me the bigness that the parts of a ruin’d wall must have,
 “to be call’d fluid? But let those, who cannot understand infinite di-
 “visibility, tell me why I should believe it more hard for almighty God
 “to create a fluid body, less than any atom, that its parts might actu-
 “ally flow, than to create the ocean. They, therefore, make me despair
 “of receiving any benefit from them, by saying, that they think air, wa-
 “ter, and other fluids, consist of solids; as if a wall, that began to fall
 “to ruin, were call’d by them a fluid body. If they may speak so, every
 “thing is fluid; for even marble itself may be broken into parts, less than
 “any atom, imagin’d by *Epicurus*.” But tho’ I make the smallness of
 the parts, whereof a body consists, one of the requisites to its being
 fluid; yet I call the various agitation of those particles the principal qua-

“are less hard, may still be sufficiently
 “solid; whence gold is specifically hea-
 “vier, tho’ less hard, than a diamond.
 “4. That compact body, whose parti-
 “cles, when press’d together, approach
 “nearer to, but yet do not slide over
 “one another, is hard and elastic, re-
 “turning to its figure with a force aris-
 “ing from the mutual attraction of its
 “parts. 5. If the parts slide upon one
 “another, the body is malleable or soft.
 “6. If the particles touch in very small
 “surfaces, the body is friable, like
 “snow, or easily separable into its parts;
 “as two polish’d marbles adhering to-
 “gether *in vacuo*, which may be disjoin’d
 “by a very small force. 7. If they
 “touch not at all, or slip easily, and
 “are of a fit size to be agitated by heat,
 “and the heat is great enough to keep
 “them in agitation, (tho perhaps much
 “less is requisite to keep water from
 “freezing) or only small, voluble, slip-
 “pery, and of a figure and bulk dis-
 “posed to motion, the body is fluid.
 “Tho the particles, even of these most
 “fluid bodies, in some measure cohere
 “together, as appears from hence, that
 “quick-silver will stand to the height
 “of sixty or seventy inches in a glass
 “tube; that water will ascend in small,
 “open pipes *in vacuo*; and that drops of
 “liquids preserve their sphericity *in va-*

“*cuo*; which is owing to the mutual at-
 “traction of their parts. Now those
 “fluid bodies, whose particles easily en-
 “tangle with one another, as those of
 “oil, or grow stiff with cold, and be-
 “come fixed, as it were, with wedges,
 “together, like those of water, will
 “easily grow hard; but if their parti-
 “cles will neither entangle, as those
 “of the air, nor grow stiff with cold, as
 “those of quick-silver, they will not
 “cohere together. 8. If the parts of a
 “body are exceeding small, dense, and
 “spherical, that body may both be fluid,
 “and much heavier than others, which
 “are harder; their particles being less
 “solid, but touching one another in
 “larger surfaces. 9. If the particles of
 “any body may be agitated every way by
 “a very brisk motion, they will, what-
 “ever be their figure, constitute a fluid,
 “as is the case of metals in fusion: but
 “such a body will presently grow hard
 “again, when that violent motion cea-
 “ses. 10. Those bodies, whose particles
 “are entangled with one another, and
 “touch in large surfaces, which are, in
 “some measure, separated, and will ea-
 “sily slide over one another, prove ei-
 “ther flexible, as leather; or very tena-
 “cious, as bird-lime, pitch, &c.” See
Newton. Optic. p. 370. and Clark. Annot. in
Robault. p. 109, 110.

PHYSICS. lification, and the chief condition of a fluid body; Mr. Hobbs, therefore, much mistakes, if he thinks that we always consider ashes and dust as fluids, absolutely speaking: I always require, in the parts of a fluid, both minuteness, and such a motion along each other, as makes them easily yield to the touch; which qualifications, how well they belong to the ruins of *Paul's*, is not very difficult to determine. Mr. Hobbs again makes use of the like example, and adds, that if we speak at this rate, every thing is fluid; for, says he, marble may be reduced to parts smaller than the atoms of *Epicurus*. But I would gladly know by what art Mr. Hobbs can divide marble into lesser particles, than such as are naturally indivisible; for such *Epicurus* makes his atoms to be: nor do I see how, in case this could be done, it proves that every thing is fluid. For, I say, that the blocks of marble, before comminution, are not fluid, either according to him or me; nay, the greatest comminution imaginable would not, according to my doctrine, make a lump of marble fluid, unless the heap, composed of the parts, how minute soever, were actually and variously set a moving amongst themselves. But he would, perhaps, have spoke more warily, if he had consider'd the difference there is betwixt saying, that all things are fluid, and that there are many solid bodies, which, by comminution, motion, and other requisite alterations, may be made parts of a fluid; as solid ice may be turned into fluid water; and quick-silver, precipitated *per se* into a red powder, be reduced to running mercury. As for what he says of an infinite divisibility of body, it is scarce worth while to examine it; for I have shewn, that this divisibility in no wise overthrows my doctrine of fluidity. Besides, I do not well understand what he means, when he says, that an infinite division is not conceivable, but an infinite divisibility easily; for since he has recourse, in this matter, to God's omnipotence, I see not why an infinite division cannot be as well conceived, as an infinite divisibility: sure an omnipotent agent is able to do what is possible to be done, and why else should a body be call'd infinitely divisible? Besides, it imports not to the controversy about fluidity, to determine what the Almighty can do, but what he actually has done. And, lastly, whereas my adversary requires to have the magnitude defined, which a part of a falling wall ought to have, to deserve the name of fluid; he should first have clearly proved, that fluidity belongs to any one single part of matter, how minute soever, and not rather to an aggregate of particles. And the corpuscles that compose a fluid body, may be of several sizes, as those of water, oil, and quick-silver; provided they be minute enough to be put into the agitation requisite to give the aggregate, they make up, the qualities necessary to denominate bodies fluid: and it is not requisite for me to define precisely the magnitudes of the parts of a fluid. Mr. Hobbs having afterwards ask'd after the causes of hardness, is answer'd, that some assign three; to which he so far agrees as to say, "but the corpuscles, such as are supposed by *Lucretius*, and also by Mr. Hobbs, "being hard before, might be easily compacted by any of these
" causes:

"causes: so that it is not (to be doubted, that the whole to be made
 "of those corpuscles will be hard." But then he would have us
 assign the cause of that he calls *durum primum*. However, himself
 answers the objection he frames against my doctrine of hardness. He
 farther demands, "if hard bodies are made out of parts originally hard,
 "why are not fluid bodies made of parts originally fluid? Could great
 "fluids, as the æther, be created, and not small ones? He who first
 "made a body hard or fluid, could, if he had pleased, have made it greater
 "or less than any other body. Now if a fluid body be made of parts
 "not fluid, and hard bodies only from hard parts, doth it not follow,
 "that neither fluid nor hard is made of original fluids?" But, first, he
 should have told us what he means by his *prima fluida*, and how he knows
 there are any such; for without this, 'twill be as hard for a considering
 man to acquiesce in his question, as to answer it. For my part, I know
 no fluid body, upon account whereof, as an ingredient, all others are
 fluid. And, I think, 'twill be hard for Mr. Hobbs to shew, that water,
 quick-silver, rectified chymical oils, &c. consist of such *fluida prima*,
 as he teaches, whereto they owe all their fluidity. And 'tis plain
 from experiments, and even the obvious changes of water and ice into
 one another, that 'tis the motion, rest, and texture of the corpuscles,
 which compose a body, that make it firm or fluid. As for what Mr.
 Hobbs demands, whether the smallest fluids imaginable could not as well
 have been created, as the æther; it proves nothing against me, the question
 not being, what might have been made, but what is so. And he
 should have answer'd the arguments I alledge, to render it improbable,
 that a fluid body is, as he would persuade us, always divisible into bodies
 equally fluid, as quantity into quantities. 'Tis true, he tells us,
 that "tho' many others do not, he understands by fluidity, that which is
 "made such by nature, equally in every part of the fluid body, in such
 "a manner as water seems fluid, and to divide itself into parts perpetually
 "fluid." But whether others will take this for a clear notion
 of fluidity, I think, may be doubted; and he should not barely say,
 but prove, that the corpuscles of water divide themselves, so as he teaches;
 since we see, that they cannot penetrate glass, and are unable to be
 driven in at the pores of more open bodies, which other liquors easily
 enter. And, lastly, to Mr. Hobbs's question, if fluids may be made
 of solids, &c. 'tis easy to give an answer, according to my doctrine;
 but till he has explain'd what he means by his *fluida prima*, and proved
 that there are such, the question needs no answer. Besides, whatever
 he, thro' mistake, strives to infer, my doctrine is so far from asserting
 that there are many parts of matter, of which neither fluid nor hard
 bodies can be made, that I teach, there are multitudes of parts,
 which may, by being reduced to sufficient smallness, and put into a convenient
 motion, or, by being brought to a mutual contact and rest, be made to
 constitute either a fluid body, or a firm one. Mr. Hobbs thus delivers

PHYSICS. delivers his own theory of fluidity and firmness: "The principles of fluidity and firmness, are nothing but rest and motion. By rest, I understand that of two parts, one with another, when they touch, but not press each other; for entire bodies of fluids may be in motion, and their fluidity remain; and hard bodies be at rest, tho' their parts are in motion." This, I doubt not, will, to most readers, seem a paradox; and as for his reasoning, I shall readily allow him, that entire fluids may move, yet preserve their fluidity; since that, I think, agrees at least as well with my hypothesis as his: but he adds, that hard bodies may rest, and yet their parts be moved, which, in one case, may be conceived, and in another not. For the implicated parts of a firm body may be made to tremble or vibrate, as those of a sounding bell, or, as in a hedge, the branches and twigs may be shaken by the wind, whilst the trees and bushes themselves continue rooted in the ground: but that in a body, the constituent corpuscles should all, or most of them, be moved quite out of their places, in respect of one another, as happens in fluids, and yet the body continue hard, is more requisite than easy to be proved. But Mr. *Hobbs* contents himself to alledge, in favour of his strange notion of fluidity and firmness, three particulars, which, I confess, afford me not the least satisfaction. The first is drawn from what he formerly taught, of the swift motion of the air in our cylinder. He adds, "and hence it is manifest, that there is a compressure in the air, thus moved and shut up, as great as the force, by which it was driven in, could make; and also, that from so great a compressure, some degree of consistence must arise, tho' less than that of water. Now if in all the same particles of air, besides the motion by which one presses another, there was also the simple circular motion, and that vehement enough, it would be almost impossible that any of them should be moved from its little circle; but that the other particles resisting the whole, would be pressed together, that is, become hard; for that is hard, of which no part gives place, but upon the motion of the whole: hardness therefore may be made in a most fluid body, by this simple circular motion of particles, which was before imparted to them by two contrary motions." But I do not see how the simple circular motion he talks of, should give such a hardness to the fluid air; nor is it manifest how the air, that perfectly fills the cylinder, can be by motion compress'd, especially so far, as thereby to obtain a degree of consistence, as he speaks, less than the consistence of water. For the cylinder being, according to him, perfectly full of air, how can the pumping make the cavity fuller than full, and consequently compress the air to a consistence, any thing near that of water, without penetration of dimensions? But if there be not a various motion in the small parts of water, whence is it that a lump of common salt, being thrown into a vessel of that fluid, is there dissolved into minute parts, many whereof are carried to the very top of the water, and so exquisitely diffused and mixed with the whole, that each

Fluidity and Firmness.

367

PHYSICS.

each drop of it contains numbers of saline corpuscles. And if motion be the cause rather of hardness than fluidity, how happens it, that in frosty weather, ice is by heat, which Mr. *Hobbs* will not deny to be motion, or an effect of it, turned from a hard to a fluid body? and that metals, whilst they are either cold, or exposed to a moderate heat, remain firm and consistent bodies; but by a violent one, which manifestly gives their parts a various and vehement agitation, gain a fluidity, which, upon their removal from the fire, they quickly exchange for firmness? To conclude, I think I need not fear, that a doctrine, which I have, perhaps, with some care, endeavour'd to establish, for the main, upon experiments, should be overthrown by opinions, the grounds whereof are such, as we have already seen; and in pleading for which, Mr. *Hobbs*, not only leaves almost all my arguments untouched, but never offers to explain, by his principles, any of those numerous and important phenomena of fluidity and firmness, which I deliver.



The MECHANICAL

The MECHANICAL

ORIGIN and PRODUCTION

OF

VOLATILITY and FIXEDNESS.

S E C T. I.

THE qualities which render a portion of matter volatile, are principally four; three whereof regard its single corpuscles, and the other the manner of their union into the body they compose. By corpuscles or the minute parts of a body, I here mean not its elementary parts, as earth or water, salt or sulphur; but such, whether simple or compound, as have their component particles so firmly united, as not totally to be disjoined or dissipated by that degree of fire wherein the matter they compose is said to be volatile or fix'd; so that they will, combined in their aggregate, either ascend or remain unraised as one intire body. Thus in sal-armoniac, whether it be a natural or a factitious thing, perfectly similar, or compounded of different parts, I look upon an intire corpuscle of it as a volatile portion of matter; so I do upon a corpuscle of sulphur, tho' when 'tis kindled it yields much acid salt; which is not extricated by bare sublimation. Thus also colcothar of vitriol falls under our consideration as a fixed body, without inquiring what cupreous or other mineral, and not wholly fix'd parts, may be united with the earthy ones; since the fires whereto we expose it, do not separate them. Now in the first place, to make a volatile body, its parts should be small, Smallness of parts. because such are more easily put into motion by the action of the fire, or other agents; and consequently more apt to be elevated by a force that tends upwards stronger than any other way. And if with this minuteness of parts, there be but a small specific gravity, their surface then being proportionably larger than in bigger particles, this will much more facilitate their elevation.

'Tis next requisite in the corpuscles of volatile bodies, that they be not too solid or heavy; for otherwise, tho' their bulk be small, they will usually be hard to elevate, on account of their great specific gravity, in respect of the air and the strength of other agents. Thus tho' the parts of

PHYSICS. red lead be very small, they cannot be easily blown about like dust or meal.

Aptness to motion.

A third qualification in a volatile body, is that its parts be conveniently shaped for motion; for if they be branched, hooked, &c. they will be apt to be stopp'd or detain'd by other bodies, or to be entangled among themselves, and consequently very difficult to be carried upwards. And this may be one reason why water, tho' specifically heavier than oil, is much more exhalable in vapour than it.

And a loose texture, or weak cohesion.

The last thing necessary in a volatile body, is that its parts cohere loosely, or so as to dispose them to be separated by the fire, in the form of fume or vapour: otherwise one part will hinder the avolation of another, and their conjunction render them too heavy or unwieldy to rise together, as intire parts. Thus a strong wind, in the spring season, is unable to carry off the lightest leaves of trees, because they then stick fast to the twigs; but in autumn, when that adhesion ceases, a gentle gale will serve to disperse them. But 'tis possible that the parts of a body may, by the figure and smoothness of their surfaces, be sufficiently apt for motion, and yet be indisposed to admit so much of it as wou'd totally separate and raise them into the air. As when salt-petre is, in a crucible, exposed to the fire, tho' a very moderate degree of heat will bring the salt to fusion, yet a greater degree of fire will not extricate so much as its spirit, and cause that to fly away.*

Five ways of introducing volatility into bodies.

This doctrine may be both illustrated, and applied, by deducing from it the general ways of volatilizing bodies, or of introducing volatility into an assigned portion of matter. And these ways seem reducible to five, which I shall severally mention, tho' both nature and art usually employ two or more of them in conjunction. For which reason, I would not, when I speak of one way, be understood to exclude the rest, as if no other concurred in it.

The first way.

The first of these ways of volatilizing a body, is by reducing it into minute parts, and *ceteris paribus*, the more minute the better. This appears from the vulgar practice of the chymists, who when they would sublime or distil antimony, sal-armoniac, sea-salt, nitre, &c. beat them to powder to facilitate their receiving a farther comminution by the action of the fire. And in some bodies this comminution ought not to be made only at first, but to be continued afterwards. For chymists find by experience, that sea-salt and nitre will very hardly afford their spirits in distillation, except they are mixed with powdered brick or bole, or some such other addition; which usually twice or thrice exceeds the weight of the salt it self. And altho' these additions, being themselves fixed, seem unlikely to promote the volatilization of the bodies mixed with them; yet by preventing the small grains of salt from melting together into one mass, and consequently keeping them in the state of comminution, they

* Volatile bodies, according to Dr. Freind, | ones, in nothing but in having their particles in his chymical lectures, differ from fixed | more minute than they.

much conduce to drive up the spirits, or the finer parts of the salts. We may add, that in some cases, the comminution is greatly to be promoted by mechanical means; and that, when the parts are brought to a great degree of smallness, they may be elevated much better than before. Thus if you mix filings of iron with sal-armoniac, some few parts may be sublimed; but if you dissolve those filings in good spirit of salt, and having coagulated the solution, calcine the greenish crystals, or *Vitriolum Martis*, that will be afforded, you may, with ease and expedition, obtain a *Crocus Martis* of very fine parts; so that I remember, when we exquisitely mix'd two parts of this fixed powder with three of sal-armoniac, and gradually urged it with a competent fire; we elevated, at the first sublimation, a great part of it; and adding a like, or a somewhat less proportion of fresh sal-armoniac to the *Caput mortuum*, we could raise so considerable a part of that also, and in it, of the *Crocus*, that if we had pursued the operation, we might, perhaps, have elevated the whole *Crocus*; which afforded a sublimate of so very astringent a taste, that it may make the trial of it in stanching of blood, stopping of fluxes, and other cases, where potent astringent is desired, worthy of a physician's notice.

The second means to volatilize bodies, is to rub, grind, or otherwise reduce their corpuscles either to a smoothness, or some fit shape, that, so they may clear themselves, or be disintangled from each other. And to this instrument of volatilization, in concurrence with the first, may probably be referred the following phenomena: in the two former of which, there is employed no additional volatile ingredient; and in the fifth, a fixed body is disposed to volatility by the operation of a liquor, carefully abstracted from it. (1.) If fresh urine be distilled, the phlegm will first ascend, and the volatile salt not rise, till that be almost totally driven away; and then it requires a considerable degree of fire to elevate it: but if you digest urine, in a well-closed glass vessel, for seven or eight weeks, that gentle warmth will cause the small parts so to rub against, or otherwise act upon, one another, that the finer ones of the salt will, perhaps, be made more slender and light; however, they will be made to extricate themselves so far, as to become volatile, and ascending in a very gentle heat, leave the greatest part of the phlegm behind them. (2.) So if must, or the artificial wine of raisins, be distilled before it hath fermented; the phlegm, but no inflammable spirit will ascend. But when this liquor is reduced to wine by fermentation, which is accompanied with a great intestine commotion, some of the parts are qualified to rise, by a very gentle heat, before the phlegm, and convene into that liquor we call spirit of wine. Nor is it only in the slighter instances afforded by animals, and vegetables, that volatility may be effected by these means: experience hath assured me, that it is possible by a long artificial digestion, wherein the parts have leisure for frequent attritions, so to subtilize the corpuscles, even of common salt, as to make them ascend in a moderate fire of sand, without the help of bole, oil of vitriol, or any volatilizing addition: and what is more considerable, the spirit would, in rising, precede the phlegm, and

The second way.

PHYSICS.

leave the greatest part thereof behind it. This intestine commotion of parts, capable of producing volatility in the more disposed portions of a body, tho' it be much easier to be found in liquors, or in moist and soft bodies, yet I have sometimes met with it in dry ones; and particularly, having caused mustard-seed to be distilled *per se* in a retort, I had a great many grains of a clear, and figured volatile salt at the very first distillation. I leave it to farther enquiry, whether in a body so full of spirits, as mustard-seed, the action and re-action of the parts among themselves, perhaps promoted by just degrees of fire, might not suffice to make in them a change equivalent, in order to volatilization, and the yielding a volatile salt, to that we have observed from fermentation and putrefaction in the juice of grapes, urine, &c. But as some trials made with other seeds, and among the rest with aromatic ones, have afforded me no volatile salt; so the success of others has sometimes made me think, that some subjects of the vegetable kingdom, whence we commonly drive acid spirits, but no dry salt, may be distilled with so regular a heat, as to afford some volatile salt; and that more bodies would be found to do this, were they not too hastily or violently urged by the fire. (3.) Tho' silver be one of the most fixed bodies we know, yet I am of opinion, that it is possible, chiefly by a change of texture, to render it volatile. An acquaintance of mine having hit upon a strange menstruum, tho' not corrosive, he abstracted it from several metals, and brought me the remainders, with a desire that I would endeavour to reduce those of lead and silver to their pristine form, which he had in vain attempted: but tho' I found the white calx of lead reducible, yet when I came to the calx of silver, I was unable to bring it into a body; and having at length melted some lead in a gentle fire, to try whether I could make it swallow up the calx, in order to a farther operation, I was surprized to find, that this mild heat made the calx of silver presently fly away, and sublime in the form of a *Farina volatilis*, which whitened the neighbouring part of the chimney and upper part of the crucible. (4.) From that which chymists themselves tell us, we may draw a good argument, *ad hominem*, to prove, that volatility depends much upon the texture, and other mechanical affections of a body. For several of those philosophers, who write of the elixir, say, that when their philosophic mercury or grand solvent, being sealed up together with a third or fourth part of gold in a glass-egg, is kept in convenient degrees of fire, the whole matter, and consequently the gold, will, by the mutual operation of the included substances, be so changed, as not only to circulate up and down in the glass, but in case the digestion or decoction should be broken off at a certain inconvenient time, the gold would be quite spoiled; being, by the past and untimely-ended operation, made too volatile, to be reducible again into gold; whereas, if the decoction be duly continued to the end, not only the gold, but all the philosophic mercury or menstruum will be turned into a sulphur or powder, of a wonderfully fixed nature. Now in this case, it is not by any thing superadded, that the most fixed body of gold is made volatile; but the same massy matter,

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consisting of gold and philosophic mercury, is, by the change of texture, occasioned by the various degrees and operations of fire upon it, brought to be first volatile, and then extremely fixed. (5.) *Helmont*, amongst other prodigious powers, which he ascribes to the alkahest, affirms, that by abstracting it often enough, it would so change all tangible bodies, and consequently stones and metals, that they might be distilled over into liquors equal in weight to the respective bodies that afforded them, and having all the qualities of rain-water; and if so, they must be very volatile. And I see not how those, who admit the truth of this strange operation, can deny, that volatility depends upon the mechanical affections of matter; since the alkahest, at least in our case, appears to work upon bodies mechanically. And it must be confessed, that the same material parts of a corporeal substance, which, when associated and interwoven, after a determinate manner, constituted a solid and fixed body, as a flint, or a lump of gold; may by having their texture dissolved, and by being freed from their former implications or cohesions, become the parts of a fluid body, totally volatile.

The third means of making a body volatile is, by associating the particles to be raised, with such as are more volatile than themselves, and of a figure fit to be fastened to them, or which are at least apt, by being added to them, to make up therewith, corpuscles more disposed to volatility than they. This being the grand instrument of volatilization, I shall be the larger upon. But I must here observe, that 'tis possible the particles of an addition, tho' not more volatile than those of the body it is mixed with, and perhaps, tho' not volatile at all, may yet conduce to volatilize the body wherewith it is mixed. For the particles of the thing added may be of such figures, and so associated with those of the body to be elevated, as in this to enlarge its former pores, or produce new ones, by intercepting little cavities, between the particles of that body, and those of the additional ingredient. For by these, and other such ways of association, the corpuscles, resulting from the combination or coalition of two or more such different particles, may, without proving too big and unwieldy, be more conveniently shaped, or more light in proportion to their bulk, and so more easily buoyed up, and sustained in the air, or otherwise more fitted for avolation, than when single.

The corpuscles of the added ingredient may contribute to the elevation of a body chiefly by two things; first, the parts of the former may be much more disposed for avolation, than is necessary to their own volatility. As when in the making of sal-armoniac, the saline particles of urine, and of foot, are more fugitive than they need to be to raise themselves; and thereby are advantaged to carry up with them the more sluggish corpuscles, whereof sea-salt consists. And next, they may be of figures so proper to fasten them to the body to be elevated, that the more fugitive will not be driven away, or disjoined from the more fixed by such a degree of heat, as is sufficient to raise them both together. To which effect, the congruity or figuration, is as well required, as the lightness or volatility of the particles

How the particles of an added ingredient may contribute to raise those of another body.

PHYSICS.

cles of the thing added. And therefore some of the most fugitive bodies we know, as spirit of wine, camphire, &c. will not volatilize many substances, which might be elevated by far less fugitive things; because the corpuscles of spirit of wine stick not to those of the body they are mixed with, but easily flying up themselves, leave those behind them, which they rather barely touch'd, than firmly adhered to; whereas, far less subtile liquors, if they be endowed with figures, which fit them for a competently firm cohesion with the body they are mixed with, will be able to volatilize it. And of this I shall give some instances in bodies very ponderous, or very fixed, or both. To begin with colcothar; which being a vitriolic calx, made by a lasting and vehement fire, is, consequently, capable of resisting such an one; yet this, when exquisitely ground with an equal weight of sal-armoniac, a salt but moderately volatile, will be in great part sublimed into those yellow flowers we call *Eus primum Veneris*; in which, that many vitriolic corpuscles of the colcothar are really elevated, will easily appear by putting a grain or two of that reddish substance into a strong infusion of galls, which thereby immediately acquires an inky colour. Steel also, (which must have endured extraordinary violences of the fire,) being reduced to filings, and diligently ground with about an equal weight of sal-armoniac, will, if degrees of fire be skilfully administered, without any previous calcination or reduction into a crocus, suffer so much of the metal to be carried up, as to give the sal-armoniac a notable colour, and a chalybeate taste. And here it will be proper to observe, for the sake of practical chymists, that the proportion of the volatile addition is to be regarded. Several bodies, thought unfit for sublimation, or incapable of having any considerable portion of them elevated, may be plentifully sublimed, if a greater proportion of the addition, than usual, is skilfully employed. Thus in the instance of filings of steel, if instead of an equal weight of sal-armoniac, the treble weight be taken, and the operation duly managed, a far greater quantity of the metal may be raised, especially if fresh sal-armoniac be carefully ground with the *Caput mortuum*. And sal-armoniac may perhaps be compounded with such other bodies, heavier than it self, as may qualify it, when it is thus clogged, to elevate some fit substances better than it would of it self alone. I shall add, that if besides the plenty of the foreign ingredient, there be a sufficient fitness of its particles, to lay hold on those of the body to be wrought on, ponderous mineral bodies may be employed to volatilize other heavy bodies. I am apt to think, that almost all metals may, by large additions and frequent cohobations, be brought to pass through the neck of the retort, in distillation; and perhaps, if they be melted, not with equal parts, but with many more, of regulus of antimony, and the process be managed as the hints now given direct, what I have said may not prove unserviceable. Many attempts have been, and are still fruitlessly made by chymists to elevate salt of tartar with additions. Now I shall only observe, that as frequent experience shews, if sal-armoniac be abstracted from salt of tartar, not only the salt of tartar is left at the bottom, but a large part of the

the sal-armoniac with it ; I suspected the cause might be, that sal-armoniac, by the operation of the alkali of tartar, is reduced into sea-salt, and an urinous one, having been at first composed of those different ingredients ; and by this means the volatile salt being loosened from the rest, flies easily away, without staying long enough to take up any other salt with it : and therefore, if this analysis of the sal-armoniac could be prevented, it seemed not impossible, that some part of the salt of tartar, as well as of colcothar and steel, might be carried up by it. And accordingly, having caused the ingredients to be exceedingly well dried, and both nimbly and carefully mixed, and speedily exposed to the fire ; I have sometimes had a portion of salt of tartar, carried up with the sal-armoniac ; but this happened so very rarely, that I suspected there must be a peculiar fitness for this work in some parcels of sal-armoniac, which are scarce, but by the effect, to be discerned from others. This, however, argues the possibility of the thing, and may serve to shew the volatilizing efficacy of sal-armoniac ; which is a compound that I recommend, as one of the most useful productions of vulgar chymistry.

*Salt of tartar
volatilized.*

But, by the way, there seems to be a great deal of difference between making a volatile salt of tartar, and the making salt of tartar volatile. It is very possible, that a man may from tartar obtain a volatile salt, and yet not be able to volatilize that tartareous salt, which has once, by incineration, been brought to a fixed alkali. There is a way, whereby some chymists obtain a volatile salt, from a mixture of antimony, nitre, and crude tartar, which, probably, comes from the latter ; but experience hath assured me, that by a distillation slowly made, without any addition, very clean tartar, or at least, the crystals of tartar, may, in conveniently shaped vessels, be brought to afford a substance, which, in rectification, will ascend to the upper part of the vessel, in the form of a volatile salt ; as if it were of urine, or of harts-horn : tho' this operation requires a dextrous and a patient distiller. But to render a fixed alkali of tartar volatile, I take to be another, and a far more difficult work ; for the common processes of performing it, promise much more than they can make good. I have convinced some of the more ingenious chymists, that the sublimed salt was not indeed the alkali of tartar, but somewhat produced by the operation, or rather extricated out of the addition. Yet I would not be thought to affirm, that it is impossible to elevate the fixed salt of tartar. For sometimes I have been able to do it, even at the first distillation, by an artificial addition, perhaps more fixed than it self ; but tho' the operation was very grateful to me, as it shewed the possibility of the thing, yet the small quantity of the salt sublimed, and other circumstances, kept me from much valuing it upon any other account. And there are other ways, whereby experience has assured me, salt of tartar may be raised. And if one of them were not so uncertain, that I can never promise before-hand, that it will succeed ; and the other so laborious, difficult and costly, that few would attempt, or be able to practice it, I should think them very valuable ; since by the former, most part of the salt

of:

PHYSICS. of tartar was quickly brought over in the form of a liquor, of a scent intolerably piercing; and by the latter, some salt of tartar of my own, being put into a retort, and urged but with such a fire, as could be given in a portable sand-furnace, there remained not at the bottom near one half of the first weight; the addition having carried up the rest, partly in the form of a liquor, but chiefly in that of a white sublimate, which was neither ill-scented, corrosive in taste, nor alkalizate, but very mild, and somewhat sweetish. And I doubt not that by other ways, the fixed alkali of tartar may be elevated, especially if, before it is exposed to the last operation of the fire, it be dextrously freed from the most of those earthy and viscous parts, which, I think, may be justly suspected to clog and bind such as are truly saline. I shall only farther intimate, that even the spurious *Sal Tartari*, volatilized with spirit of vinegar, may, if well prepared, make amends for its empyreumatical smell and taste; and, in several cases, be of no despicable use, both as a medicine and a menstruum.

Repeated sublimations do not always increase the quantity of the sublimate.

There is a phenomenon, which may much surprize, and sometimes disappoint those who deal in sublimations, unless they are fore-warned of it. For though it be taken for granted, that by carefully mixing what is sublimed, with what remains, and re-subliming the mixture; a greater quantity of the body to be sublimed may be elevated the second time, than was the first; and the third time than the second, and so on; yet I have not found this rule always to hold true; but in some bodies, as particularly in some kinds of dulcified colcothar, the sal-armoniac would, at the first sublimation, carry up more of the fixed powder, than at the second or third. So that I was, by several trials, persuaded, when I found a very well and highly coloured powder elevated, to lay it by for use, and thereby save my self the labour of a prosecution, which would not only have proved useless, but prejudicial. And by often returning sal-armoniac upon crude antimony, though the sublimate, obtained by the first operation, was, much of it, variously coloured; yet, afterwards, the salt ascended, from time to time, gradually paler, leaving the antimony behind it: which way of making minerals more fixed and fusible, I conceive may be of great use in some medicinal preparations. But I chiefly intend here to consider, whether the present phenomenon may be ascribed to the repeated action of the fire, grinding together the bodies to be raised; whence either the corpuscles of the sal-armoniac, or of the other body, may have those little hooked, or equivalent particles, whereby they take hold of one another, broken or worn off; and whether the indisposition of the colcotharine or antimonial parts to ascend, may not in some cases be promoted by their having, from frequent attritions, so smoothed their surfaces, that several of them may closely adhere, like pieces of polished glass, and so make up clusters too unwieldly to be raised, as the single corpuscles they consist of were; which change may dispose them to be, at once, less volatile, and more fusible. And here it may be

serviceable to observe, that sublimations are applicable to make very fine comminutions of several bodies. That those which are elevated are reduced to a great fineness of parts, is obvious in many examples, whence it has been anciently said, that sublimations are the chymist's pestles; since they really resolve the elevated bodies, into exceeding fine flower, and much finer than the pestle and mortar can reduce them. But what I intend is, that sometimes, even bodies so fixed, as not at all to ascend in sublimation, may yet be reduced, by that operation, into powders extremely fine. For tho' chymists complain much of the difficulty of making a good calx of gold, and of the imperfection of the few ordinary processes, prescribed to make it; yet, we have found, upon trial, that by exactly grinding a thick amalgam of gold and mercury, with a competent weight of finely powdered sulphur, we may, upon putting the mixture to sublime in a conveniently-shaped glass, by degrees of fire, obtain a cinnabar, which will leave behind it a fine calx of gold, than can be had from some far more difficult processes.

To proceed to our fourth way. Volatility depends so much upon the contexture of the corpuscles, which are to be raised together, that even very ponderous bodies may serve for volatilizing ingredients, if they be disposed to fasten themselves sufficiently to the bodies they are to carry up along with them. For quicksilver, being united by amalgamation with a small proportion of lead, will, by a moderate fire, and in close vessels be made to carry over with it some of the lead; as we have found by the increased weight of the quicksilver, that passed into the receiver; which, by the way, may make us cautious, how we conclude quicksilver to be pure, merely from its having been distilled. There remains but one body more heavy than those we have mentioned, and that is gold; which being of a surprizing fixity, I do not wonder that the wary naturalists, and the more severe among the chymists, should think it incapable of being volatilized. Yet if we consider, how very minute parts gold may be rationally supposed to consist of, and to be divisible into; methinks it should not seem impossible, that if we could light on volatile salts, of figures fit to stick fast to the corpuscles of the gold, they would carry up with them particles, whose solidity can scarce be more extraordinary than their minuteness: and in effect, we have made more than one menstruum, with which some particles of gold may be carried up. But when I employed my *Menstruum peracutum*, (which consists of spirit of nitre, several times drawn from butter of antimony,) I was able, without a very violent fire, and in a few hours, to elevate so much crude gold, as, in the neck of the retort, afforded me a considerable quantity of sublimate; which I have had, red as blood: and that it consisted partly of gold, manifestly appeared by this, that I was able, with ease, to reduce that metal out of it.

But in reckoning up the instruments of volatilization, we must not omit to mention the air; which I have often observed to facilitate the elevation

*The fourth way
of introducing volatility into bodies.*

PHYSICS.

tion of some bodies, even in close vessels. And, though to fill these high, be judged, by many, a short method, because the steams have then a less way to ascend; yet frequent experience has informed me, that, at least in some cases, they take wrong measures, and that a large proportion of air, purposely left in the vessels, may more than make amends for the greater space, that is to be ascended by the vapours or exhalations of the matter to be distilled or sublimed. And if, in close vessels, the presence of the air may promote the ascent of bodies; it may well be expected, that the elevation of several of them may be furthered by being attempted in open vessels, to which the air hath free access. And if we may credit the probable relations of some chymists, the air much contributes to the volatilization of particular bodies, which are barely exposed to it. But the account on which the air, by its bare presence, or peculiar operations conduceth to the volatilization of some bodies, is a thing very difficult to be determined, without a due regard to gravity, levity, and the constitution of the corpuscles that compose the air, which I take to be very numerous, and various.

I have hitherto generally considered the small portions of matter, to be elevated in volatilization, as intire corpuscles; but there may also happen cases, wherein a kind of improper volatilization is effected, by making use of such additions, as break off, or otherwise divide the particles of the corpuscles to be elevated; and, by adhering to, and so clogging one of the particles, to which it proves more fit, enable the other, which is now brought to be more light, or disengaged, to ascend. Thus, when sal-armoniac is well ground with *Lapis Calaminaris*, or with some fixed alkali, and committed to distillation; the sea-salt, which enters the composition of the sal-armoniac, being detained by the stone, or the alkali, there is a divorce made between the common salt, and the urinous, and fuliginous salts, that were incorporated with it; and being now disengaged from it, are easily elevated. And I have observed, in human urine, a kind of native sal-armoniac, much less volatile than that sublimed from human blood, harts-horn, &c: and therefore, supposing a separation of parts may be made by an alkali, as well in this salt, as in the common factitious sal-armoniac, I put to fresh urine a convenient proportion of the salt of pot-ashes; and distilling the liquor, it yielded a spirit more volatile than the phlegm; and of a very piercing taste: which way of obtaining a spirit, without any violence of fire, and without either previously abstracting the phlegm, or waiting for the fermentation of stale urine, I taught some chymists, because of the usefulness of spirit of urine, which being obtained by this innocent way, might, probably, be employed, with much less suspicion of corrosiveness, than if quick-lime had been used in the operation. And in making spirit of nitre, by mixing salt-petre with oil of vitriol, and distilling them together; the oil so divides or breaks the corpuscles of the nitre, that the new disposed particles of that salt, which amount to a great portion of the whole, will be made easily to ascend, even with

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a moderate sand-heat, and sometimes without any fire at all, in the form of a spirit, exceeding subtile, and volatile.

The last means of volatilizing bodies is, the operation of the fire, or some other actual heat. But of this, which is so obvious, it were needless to discourse. I shall only intimate, that there may be bodies, which, in such degrees of fire, as are usually given in the vulgar chymical operations, will not rise, may yet be forced up by such violent and lasting fires, as are employed by the melters of ores, and founders of guns, and sometimes by glass-makers. And indeed, tho' I here consider volatility and fixedness in the popular sense of those terms; yet if we would view the matter more strictly, I presume, we should find, that they are but relative qualities, and to be estimated, especially the former, by the degree of fire, to which the body, whereto we ascribe one or other of these qualities, is exposed; and therefore it is much more difficult, than men are aware of, to determine accurately, when a body ought to be accounted volatile, and when not; since there is no determinate degree of heat agreed on, nor indeed easy to be devised, for a standard, whereby to measure volatility and fixedness: and it is obvious that a body, which remains fixed in one degree of fire, may be forced up by another. Besides, a body may pass for absolutely fixed, among the generality of chymists, and yet be unable to endure the fires of founders and glass-makers. Having not observed, that chymists had examined the fixity of other bodies than metalline ones by the cupel, I put dry salt of tartar upon it; and found, that in no long time it manifestly wasted in so vehement a heat, whilst also the air came freely at it. And having well mixed one ounce of good salt of tartar with treble its weight of tobacco-pipe-clay, we kept them but for two or three hours in a strong fire; yet the crucible being purposely left uncovered, we found the salt so wasted, that the remaining mixture afforded us not near a quarter of an ounce of salt. And indeed I scarce doubt, that in strictness, several of those bodies, which pass for absolutely fixed, are but comparatively and relatively so, that is, in regard to such degrees of fire, as they are usually exposed to in the distillations, sublimations, &c. of chymists. And, perhaps, even the fires of founders and glass-makers, are not the most intense, that might, possibly, be made in a short time, provided only small portions of matter were to be wrought on by them. In effect, I know very few bodies, besides gold, that will persevere totally fixed in the most vehement degrees of fire wherewith I have made experiments. And though tin is in our chymical reverberatories usually reduced but into a calx, which is reputed very fixed; yet in those intense fires, which an acquaintance of mine uses in his tin works, quantities of tin are often carried up to a considerable height, in the form of a whitish powder, which being in large masses forced off from the places, whereto it had fastened itself, yields, by a skilful reduction, great quantities of good malleable metal, that seems to me rather more fine than ordinary tin.

S E C T. II.

*Qualifications
for fixedness in
bodies.*

Fixedness being the opposite quality to volatility, what we have discoursed of the former, will help to clear up the nature of the latter.

The qualifications most conducive to render a portion of matter fixed, seem to be, 1. the grossness or bulk of its component parts. 2. The ponderosity or solidity of them. 3. And lastly, an indisposition of their corpuscles for avolation, arising from the texture of the body. And from these causes or requisites of firmness, may be deduced the following means of giving or adding fixation to a body, which was before either volatile or less fixed: and they are reducible to two general heads; the action of the fire, as the parts of the body exposed to it, are thereby made to operate variously on one another; and to the association of the particles of a volatile body, with those of some proper additional one. But these two instruments of fixation being general, I shall propose four or five more particular ones.

*The first way of
producing fixed-
ness, by means of
fire, or the addi-
tion of other mat-
ter.*

And first in some cases, it may conduce to fixation, that, either by an addition, or by the operation of the fire, the parts of a body be brought to touch each other in large portions of their surfaces. For, that from this contact, there must follow such a mutual cohesion, as will at least indispose the touching corpuscles to suffer a total divulsion, may appear from the cohesion of flat pieces of marble and glass, and from some other phenomena belonging to the history of firmness; whence we may properly borrow some instances, for illustration, in the doctrine of fixedness; since, usually, the same things, which make a body firm, give it a degree of fixedness, in keeping it from being dissipated by the usual degrees of heat and agitation of the air. Besides this, 'tis not impossible, that the bare operation of the fire may, in some cases, procure a cohesion among the particles, as well as disjoin them in others, and thereby make them more volatile. For, as in some bodies, the action of the fire may rub off the little hooks, that entangle them, and make it more easy for the corpuscles to be disengaged, and fly upwards; in others the agitation of the fire may grind their surfaces so smooth, as to admit of a firm contact and cohesion. Thus in grinding glasses for telescopes and microscopes, the artificer, by long rubbing a piece of glass against a metalline dish, brings the two bodies to touch one another, in so many parts of their surfaces, that they will most firmly adhere to one another. And if two grosser corpuscles, or a greater number of smaller be thus brought to stick together, their aggregate will prove too heavy to fly away. And to shew that the fire may effect a levigation in the surfaces of some corpuscles, I have caused *Minium*, and other calces to be melted in a vehement fire, whereby that which was before a dull and incoherent powder, was reduced into much grosser corpuscles; multitudes
of

of their grains appearing smooth, glittering, and almost specular, like those of fine litharge of gold: and the masses which these grains composed, were usually solid, and of difficult fusion. When we make glass of lead *per se*, it is plain, that the particles of the lead are reduced to a great smoothness; since wheresoever you break the glass, the surfaces produced will not be jagged, but smooth, and considerably specular. It seems, also, possible, that even when the fire doth not make any great attrition of the particles of the body to be fixed, it may yet occasion their sticking together; because it may at length, after multitudes of revolutions, and occurrences, bring those of their surfaces to join, which by reason of their breath, smoothness, or congruity of figure, are fit for mutual cohesion; and when once they come to stick, there is no necessity, that the same causes, which were able to make them pass by one another, when their contact was only in an inconsiderable part of their surfaces, should have the same effect now, when their contact is full; though perhaps, if the degree of fire was much increased, a more vehement agitation would surmount this cohesion, and dissipate, again, these clusters of coalescent particles.

These conjectures will appear the less extravagant, if we consider what happens in quick-silver made precipitate *per se*. For here, running mercury is exposed to a moderate fire for a considerable time, whereby the parts of the mercury are variously agitated, and many of them made to ascend; till convening into drops on the sides of the glass, their weight carries them down again; but at length after many mutual occurrences, and perhaps attritions, some of the parts begin to stick together in the form of a red powder, and then gradually, more and more, and mercurial particles are there fastened together, till at length, all, or by much the greater part of the mercury is reduced into the like precipitate; which, by this cohesion of parts, being grown more fixed, will not, with the same degree of heat, be made to rise and circulate, as the mercury would before; yet I have found by trial, that with a greater and a competent degree of heat, this precipitate *per se* would, without the help of any volatilizing ingredient, be easily reduced into running mercury again. Chymists, who agree in supposing this precipitate made without any addition, will scarce be able to give a more probable account of the consistence obtained by the mercury; wherein, since no body is added to it, there appears to be wrought none but a mechanical change. And though I have suspected, that in philosophical strictness, this precipitate may not be made *per se*, but that some penetrating particles of the fire, especially saline ones, may have associated themselves with the mercurial corpuscles; yet, even upon this supposition, it may be said, that these particles contribute to the effect, but by facilitating the mutual cohesion of corpuscles, that would not otherwise stick to one another. And, as for the generality of chymists, who assert the transmutation of all metals into gold, by the philosopher's stone, they must grant it probable, that a new and fit contexture of the parts of a volatile body, may greatly

PHYSICS, ly contribute to render it highly fixed. For, it is averr'd by *Helmont*, who pretended not to the elixir, that a grain of a powder, which was given him, transmuted a pound of running mercury; where the proportion of the elixir to the mercury was so inconsiderable, that it cannot reasonably be supposed, that every corpuscle of the quick-silver, which before was volatile, became extremely fixed, merely by its coalition with a particle of the powder; since, to make one grain suffice for this coalition, the parts it must be divided into, will be scarce conceivably minute; and therefore each single part was not likely to be fixed itself; or at least it was more likely to be carried up by the mercury, than to keep that from flying away: whereas, if we suppose the elixir to have made such a commotion among the corpuscles of the mercury, as to bring them to stick to one another, it is agreeable to the mechanical doctrine of fixedness, that the mercury should endure the fire as well as gold, on account of its new texture, which, supposing the story true, appears to have been introduced, by the new colour, specific gravity, indissolubility in *Aqua fortis*, and other qualities, wherein gold differs from mercury; but especially malleableness, which usually requires, that the parts, from the union whereof it results, be either hooked, branched, or otherwise adapted and fitted to make them take fast hold of, or stick close to one another. And since in the whole mass of the factitious gold, all, except one grain, must be materially the same body, which, before the projection, was quick-silver; we see, how great a proportion of volatile matter may, by an inconsiderable quantity of addition, acquire such a new disposition of its parts, as to become most fixed. However, this instance agrees much better with the mechanical doctrine, than with this vulgar opinion of the chymists, that, if in a mixture, the volatile part much exceeds the fixed, it will carry up this with it, and on the contrary. But though the rule holds in many cases, where there is no peculiar indisposition to the effect that is aimed at; yet, if the mechanical affections of the bodies be ill suited to such a purpose, our philosophical experiment manifestly proves, that the rule is false; since so great a multitude of grains of mercury, instead of carrying up with them one grain of the elixir, are detained by it in the strongest fire.

*A second way
by altering or expelling the volatile particles.*

The second way of producing fixedness, is by expelling, breaking, or otherwise disabling those volatile corpuscles, which are too indisposed to be fixed themselves; or are fitted to carry up with them such particles as would not, without their help, ascend. That the expulsion of such parts is a proper means to make the aggregate of those, which remain, more fixed, will not want proof, if we consider the instance of it in foot; where, though many active parts were, by the violence of the fire, and the current of the air, carried up together by the more volatile parts; yet when the foot is well distilled, in a retort, a competent time being allow'd for the extrication and avolation of the other parts, there will, at the bottom, remain a substance, which will not now fly away, as before. And here let me observe, that the recess of the fugitive corpuscles may contribute to the fixation

of a body, not barely because the remaining matter is freed from so many volatilizing parts, but because upon their absence, the pores or intervals, they leave behind, are filled up with more solid or heavy matter; and the body becomes more homogeneous, close and compact. And, besides the expulsion of unfit corpuscles, which may be otherwise disabled from hindering the fixation of the mass they belong to; it seems very possible, that in some cases they may, by the action of the fire, be so broken, as with their fragments to fill up the pores or intervals of the body they appertain'd to; or may make such coalitions with the particles of a convenient addition, as to be no impediment to the fixity of the whole mass, though they remain in it.

The third means of fixing bodies, is, by preserving that rest among the parts, whose contrary is necessary to their volatilization. And this may be done by preventing or checking that heat, or other motion, which external agents strive to introduce into the proposed body. But this tending rather to hinder the actual avolation of a portion of matter, or, at most, to procure a temporary abatement of its volatility, than to give it a stable fixity, I shall not any longer insist on it. *A third way, by securing rest.*

The fourth way of producing fixedness in a body is, by putting to it such an appropriated addition, whether fixed or volatile, that the corpuscles of the body may be put among themselves, or with those of the added ingredient into a complicated state. This being the usual and principal way of producing fixity, we shall dwell the longer upon it, and give instances of several degrees of fixation. And first we find, that a fixed addition may easily give a degree of fixity to a very volatile body. Thus spirit of nitre, which will, of itself, easily fly away in the air, having its saline particles associated with those of fixed nitre, or salt of tartar, will, with the alkali, compose a salt of a nitrous nature, capable of being melted in a crucible, without loss of its spirit. And I have found that the spirit of nitre, which abounds in *Aqua fortis*, being coagulated with the silver, they corrode, and the crystals produced by their coalition, being put into a retort, may be kept for some time in fusion, before the metal will let go the nitrous spirit. When we poured oil of vitriol upon the calx of vitriol, though many particles were driven away by the excited heat; yet the saline parts, which combined with the fixed ones of the colcothar, stuck fast to them. And if oil of vitriol be, in a due proportion, dropp'd upon salt of tartar, there results a *Tartarum Vitriolatum*, wherein the acid and alkaline parts cohere so strongly, that it is not an ordinary degree of fire that can disjoin them; whence several chymists have thought this compound salt to be indestructible. But a less heavy liquor than the oil of vitriol, may, by an alkali, be more strongly detained, than that oil itself; for experience has assured me, that spirit of salt, being dropp'd, to satiety, upon a fixed alkali, there will be made so strict an union, that a strong and lasting fire cannot so much as melt the mixture. *A fourth way, by complicating the parts.*

But

PHYSICS.

But it is not the bare mixture of volatile particles with fixed ones, that will suffice to elevate the latter. For unless the figures of the latter be correspondent, and fitted to fasten to the other, the volatile parts will fly away in the heat, and leave the rest as fixed as before. Thus, when sand or ashes are wetted with water, they quickly part with that water, without parting with any degree of their fixity. On the other side, it is not always necessary, that the body, which is fitted to destroy, or greatly abate the volatility of another, should be itself fixed. For, if there be a skilful coaptation of the figures of the particles of both the bodies, these particles may take such hold of one another, as to compose corpuscles, which will neither, by reason of their strict union, be divided by heat, nor by reason of their resulting grossness be elevated even by a strong fire, or at least by such a degree of heat, as would have sufficed to raise more indisposed bodies, than either of the separate ingredients. In preparing the *Bezoardicum Minerale*; though the rectified butter or oil of antimony, and the spirit of nitre, here put together, are both distilled liquors, yet the powder, which results from their union, is so far fixed, that after 'tis edulcorated with water, 'tis calcined for five or six hours; which operation it could not bear, unless it had attained to a considerable degree of fixation. I here suppose, with the generality of chymists, that the addition of a due quantity of spirit of nitre is necessary to be employed in making the *Bezoardicum Minerale*. But if it be a true observation, which is attributed to *Billichius*, that a *Bezoardicum Minerale* may be obtained without spirit of nitre, barely by a slow evaporation, (made in a glass dish,) of the more fugitive parts of the oil of antimony; the instance will not, indeed, be proper in this place; but it belongs, however, to the second way of introducing fixity. Again, if you take strong spirit of salt, and satiate it with the volatile spirit of urine; the superfluous moisture being abstracted, you will obtain a compound salt, scarce, if at all, distinguishable from sal-armoniac; and which will not, as the salts it consists of, before their coalition, easily fly up into the air, but require a considerable degree of fire to sublime it.

I lately mentioned, that the volatility of the spirit of nitre may be much abated by coagulating it into crystals, with particles of corroded silver; I shall now add, that such nitrous spirits may be made much more fixed by the addition of the spirit of salt, which, if it be good, will, of itself, fume in the air. For having dissolved a convenient quantity of crystals of silver, in distilled water, and precipitated them, not with a solution of salt, but the spirit of salt, the phlegm being abstracted, and some few of the looser saline particles; though the remaining mass was urged with a violent fire, which kept the retort red-hot for a considerable time; yet the nitrous and saline spirits were not at all driven away from the silver, but continued in fusion with it; and when the mass was taken out, these spirits so abounded in it, that it had no appearance of a metal, but looked rather like a thick piece of horn.

VOLATILITY *and* FIXEDNESS.

385

PHYSICS.

The next instance is afforded us by that kind of turbita, which may be made by oil of vitriol, instead of the *Aqua fortis* employed in the common *Turpethum minerale*. For though oil of vitriol be a distilled liquor, and mercury a volatile body; yet when we abstracted four or five parts of oil of vitriol from one of quick-silver, and then washed off as much as we could of the saline particles of the oil of vitriol, those which remained, adhering to the mercury, render'd it far more fixed, than either of the liquors had been; and enabled it, even in a crucible, to endure a surprizing degree of fire, before it could be driven away. The like turbita may be made with oil of sulphur *per campanam*. But this is nothing, to what *Helmont* tells us of the operation of his alkalest; where he affirms, that this menstruum, which is volatile, being abstracted from running mercury, not only coagulated it, but left it so fixed, as to endure fires excited by the utmost force of bellows. If this be certain, it will not be a slender proof, that fixity may be mechanically produced; for if there remain some particles of the menstruum with those of the metal, it will not be denied, that two volatile substances may perfectly fix one another. And even this will appear less improbable from some farther instances. Having put a mixture, made of a certain proportion of two dry volatile bodies, (*viz.* sal-armoniac, and very fine powder of sulphur,) to half its weight of common running mercury, and elevated this mixture three or four times from it, the mercury, which lay at the bottom, in the form of a ponderous, purplish powder, was, by this operation, so fixed, that it long endured a strong fire, which, at length melted the glass, and kept it so, without forcing up the mercury; which, by the way, as we found upon some trials, seemed to have its salivating, and emetic powers greatly infringed, and sometimes quite suppress'd. In the remaining instances, I shall employ only one menstruum, oil of vitriol, and shew the efficacy of it, in fixing some parts of volatile bodies, with some parts of itself; by which examples it will appear, that a volatile body may not only lessen the volatility of another body; but that two substances, which apart were volatile, may compose a third, which will be less volatile, and even considerably fixed. We mixed, by degrees about equal parts of oil of vitriol, and oil of turpentine; and though each of them single, especially the latter, will ascend with a moderate fire, in a sand-furnace; yet after distillation, we had a considerable quantity, sometimes a fifth or a sixth part of a coal-black *Caput mortuum*, able to endure the fire. And to give a higher proof of the disposition, which oil of vitriol hath, to let some of its parts grow fixed, by combination, with those of an exceeding volatile liquor, I mixed it with an equal or double weight of highly rectified spirit of wine, and found, that the fluid parts of the mixture being totally abstracted, there would remain a considerable quantity of a black substance, fixed to admiration. And because camphire is esteemed the most fugitive of consistent bodies, since being but laid in the free air, without any help of the fire, it will wholly vanish; I tried what oil of vitriol, abstract-

PHYSICS.

ed from camphire would do, and found at the bottom of the retort a greater quantity, than one would expect, of a substance, black as pitch, and wanting almost as much of the volatility, as of the colour of camphire; though it appeared not, that any of the gum had sublimed into the neck of the retort.

From all these instances it manifestly follows, that, in many cases, there needs nothing to make associated particles, whether volatile or not, become fixed; but either to interweave or entangle them among themselves, or bring them to touch one another in large portions of their surfaces, or by both these ways together, or by some others, to procure a firm cohesion of so many particles, that the resulting corpuscles shall prove too big or heavy to be driven up into the air, by that degree of fire, wherein they are said to be fixed.

* Sir Isaac Newton, whose words we can never use too much, instructs us, also, in the nature of fixedness and volatility. "The particles of fluids, (says that great philosopher,) which do not cohere too strongly, and are of such a smallness, as renders them most susceptible of those agitations, which keep liquors in a fluor, are most easily separated and rarified into vapour; and in the language of the chymists they are volatile, rarifying with an easy heat, and condensing with cold. But those which are grosser, and so less susceptible of agitation, or cohere by stronger attractions, are not separated without a stronger heat, or perhaps not without fermentation. And these last are the bodies which chymists call fix'd; and being rarified by fermentation, become true permanent air: those particles receding from one another, with the greatest force; and being most difficultly brought together, which upon contact, cohere most strongly. And because the particles of permanent air are grosser, and arise from denser substances than those of vapours; thence it is that true air is more ponderous than vapour; and that a moist atmosphere is lighter than a dry one, quantity for quantity". *Newton. Optic, p. 371, 372.* Hence easily arises a rational account of those two chymical operations, distillation and sublimation, which Sir Isaac Newton thus delivers. "When oil of vitriol is mixed with a little water, or is run *per deliquium*, and, in distillation, the water ascends difficultly, and brings over with it some part of the oil of vitriol, in the form of spirit of vitriol; and this spirit being poured upon iron, copper, or salt of tartar, unites with the body, and lets go the water; doth not this shew that the acid spirit is attracted by the water, and more attracted by the fixed body than by the water, and therefore lets go the water to cohere with the fixed body? And is it not for the same reason that the water and acid

"spirits, which are mixed together in vinegar, *Aqua fortis*, and spirit of salt, cohere and rise together in distillation; but if the menstruum be poured on salt of tartar, or on lead, or iron, or any fix'd body which it can dissolve, the acid by a stronger attraction adheres to the body and lets go the water? And is it not also from a mutual attraction, that the spirits of foot and sea-salt unite and compose the particles of sal-armoniac, which are less volatile than before, because grosser and freer from water; and that the particles of sal-armoniac, in sublimation, carry up the particles of antimony, which will not sublime alone; and that the particles of mercury uniting with the particles of acid spirit of salt, compose mercury sublimate, and with the particles of sulphur compose cinnabar; and that the particles of spirit of wine and spirit of urine, well rectified, unite, and letting go the water that dissolved them, compose a consistent body; and that in subliming cinnabar from salt of tartar, or from quick-lime, the sulphur, by a strong attraction of the salt or lime, lets go the mercury, and stays with the fixed body; and that when mercury sublimate is sublimed from antimony, or from regulus of antimony, the spirit of salt lets go the mercury, and unites with the antimonial metal, which attracts it more strongly, and stays with it till the heat be great enough to make them both ascend together, and then carries up the metal with it in the form of a very fusible salt, called butter of antimony, though the spirit of salt alone be almost as volatile as water, and the antimony alone as fix'd as lead? - - When arsenic with soap gives a *Regulus*, and with mercury sublimate, a volatile fusible salt, like butter of antimony, doth not this shew that arsenic, which is a substance totally volatile, is compounded of fix'd and volatile parts, strongly cohering by a mutual attraction, so that the volatile

"latile will not ascend without carrying up the
 "fixed? And so when an equal weight of spirit
 "of wine, and oil of vitriol are digested toge-
 "ther, and in distillation yield two fragrant and
 "volatile spirits, which will not mix with one
 "another, and a fixed black earth remains behind;
 "doth not this shew that oil of vitriol is com-
 "posed of fix'd and volatile parts strongly united
 "by attraction, so as to ascend together in the
 "form of a volatile and fluid salt, till the spirit
 "of wine attracts and separates the volatile
 "parts from the fixed? And therefore, since
 "oil of sulphur *per campanam* is of the same
 "nature with oil of vitriol, may it not be in-
 "fer'd, that sulphur is also a mixture of vo-
 "latile and fix'd parts, so strongly cohering by
 "attraction, as to ascend together in sublima-
 "tion? By dissolving flowers of sulphur, in oil
 "of turpentine, and distilling the solution, 'tis
 "found, that sulphur is composed of an inflam-
 "mable thick oil or fat bitumen, an acid salt, a
 "very fix'd earth, and a little metal. The three
 "first were found not much unequal to one an-
 "other, the fourth in an almost inconsiderable
 "quantity. The acid salt dissolved in water, is

"the same with oil of sulphur *per campanam*,
 "and abounding much in the bowels of the earth,
 "and particularly in marcasites, unites itself to
 "the other ingredients of the marcasite, which
 "are bitumen, iron, and earth; and with them
 "compounds alum, vitriol, and sulphur; with
 "the earth alone, it compounds alum; with the
 "metal alone, or metal and earth together, it
 "compounds vitriol; and with the bitumen and
 "earth, it compounds sulphur. Whence it
 "comes to pass, that marcasites abound with
 "these three minerals. And is it not from the
 "mutual attraction of the ingredients, that they
 "stick together for compounding these minerals;
 "and that the bitumen carries up the other in-
 "gredients of the sulphur, which without it
 "would not sublime? And the same question
 "may be put concerning all, or almost all the
 "gross bodies in nature. For all the parts of
 "vegetables and animals are composed of sub-
 "stances volatile and fixed, fluid and solid, as ap-
 "pears by their analysis: and so are salts and
 "minerals, as far as chymists have hitherto been
 "able to examine their composition. *Newton.*
Optic. p. 356—360.



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EXPE.

EXPERIMENTS

Relating to the

Superficial Figures of Fluids.

Various experiments to discover and illustrate the phenomena of contiguous fluids.

PERhaps not the thousandth part of the universe, yet known to us, is form'd into solid bodies; and consequently all the rest is made up of celestial fluids, and the atmospheres of solids; and these fluids may, possibly, have distinct surfaces: whence, to observe and consider the effects of the agreement and disagreement which such fluids, as fall under sensible observation, have, when contiguous to one another, or to the surfaces of solids, may chance to illustrate the formation of those great masses of matter, of which the divine architect has form'd the parts of the universe. I shall here therefore nakedly propose the experiments I have made, with relation to this matter; leaving it to others to reason upon them.

1. Having poured a menstruum made of fixed nitre, dissolved by the moisture of a cellar, into a glass-pipe, sealed at one end, and not a quarter of an inch in diameter; that the concave surface of the fluid might be the more conspicuous; we gently poured on it some highly rectified spirit of wine, which we knew would not mix with, but swim above it; and presently found the figure of the surface of the lower liquor changed, and the cavity quite destroyed; the surface, which seemed, as it were, common to the two contiguous liquors, appearing flat or horizontal. And such a level superficies we had, by putting these two liquors together in a much wider glass.

2. By employing oil of turpentine, instead of the spirit of wine, the liquor almost lost its concavity.

3. But common water, being put into the pipe, retain'd its concave surface, though we added to it some oil of turpentine, and left it long to rest upon the water.

4. Some pure oil of gum guajacum, being poured into a slender pipe, we found the upper superficies of it concave; like that which
water

water would have had in the same tube. But putting a little water upon this oil, it presently changed the figure of its surface, which then became visibly convex.

5. Having put some oil of tartar into the pipe, and added some drops of the oil of guajacum to it; this liquor did not manifestly alter the concave figure of the surface of the alkaline liquor, as the oil of turpentine had done. And having warily poured a little water upon the oil of guajacum, the upper superficies of it changed presently from concave to convex, so that this oil, in the midst of the other two liquors, appeared like a little red cylinder; which, instead of having circular bases, was protuberant at both ends; but most at that which touched the oil of tartar.

6. Some essential oil of cloves being put into a new slender pipe, and observing it to be somewhat concave at the top, where it was contiguous to the air, we added a little common water to it, and found the surface of the oil also to be tumid. And in regard this liquor, as well as the fore-mentioned oil of guajacum, tho' it were so heavy as to sink in the water, would not do so in deliquated salt of tartar, we did, into another slender pipe, put first some of this last named liquor, then some of the aromatic oil; and lastly, a little common water; and found that the little cylinder of oil, appeared conyex at both ends; but more so at the upper, where it was contiguous to the water.

7. Into a little slender glass, that was much longer, but of like bore with the former, we put a small quantity of quick-silver, and having taken notice, how the upper superficies swelled in the middle, above the level of the parts, where it touched the glass, we poured some water upon it, and found a manifest and considerable depression of the surface, tho' the protuberance were not quite depressed.

8. This experiment having been frequently repeated, sometimes it seemed, that when the aqueous cylinder was much longer, the depression of the mercurial surface was somewhat greater. But this did not constantly happen. We often observed, that, tho' a very little water sufficed, by its contact, manifestly to abate the protuberance of the quick-silver; yet it had not the same effect on that ponderous fluid, as when, being increased almost as high as the length of the pipe would permit, a greater weight of it was incumbent on the mercury; for then I manifestly perceived, that the surface of the quick-silver, being depressed almost to a level, in those parts of it which were near the inside of the glass, there was, about the middle of the surface, an elevation of the mercury, that appeared to be rather more than an hemisphere, and rose to the height of its full semi-diameter above the rest of the mercurial surface; and in that state it continued as long as I thought fit to let it. And lest this trial should impose upon me, I caused it to be more than once repeated. I afterwards caused the incumbent water, to be sucked up by degrees, and found, that when the incumbent water began to be too much shortened, the little segment of the sphere, began to be somewhat flattened, and subsided more and more, as the water was taken off.

9. Having

PHYSICS.

9. Having conveyed two slender pipes into a pneumatical receiver, one of them furnished with common water, and the other with quick-silver, we caused the common air to be well exhausted, without observing any sensible change in the concave figure of the water: but as for the quick-silver, I knew not what to conclude about it. For having repeated the trial twice or thrice, it sometimes seemed manifestly to be more protuberant upon the exhaustion of the receiver, than when it was put in; especially when its figure was attentively viewed, and the external air suffered to re-enter with all convenient celerity. But that which yet kept me doubtful was, that I observed, upon taking off the air's pressure from the quick-silver, there disclosed themselves some little bubbles, which, I feared, we had not been able to free it altogether from, and which might be suspected to have some interest in the phenomenon. We also conveyed into our receiver, a clear chymical oil, heavier than water, and whilst it was contiguous to that fluid, it had a convex surface; also having placed the pipe furnished with both liquors in the pneumatical receiver, we pumped out the air, without finding that the oil sensibly altered its protuberant surface, as neither did the water lose the concave figure of its upper superficies.

10. I took fixed nitre, (or salt of tartar) resolved, *per deliquium*, into a transparent liquor; and having half filled a clear vial with it, I poured on it a convenient quantity of vinous spirit exactly rectified, that no phlegm might occasion an union betwixt the two liquors, which ought, as ours did, to retain distinct surfaces, and soon regain them, tho' the glass were well shaken. Then having found by trial, that common oil of turpentine, if employed in a competent quantity, will not totally dissolve in spirit of wine; and having also observed, that if this spirit of wine be exquisitely rectified, the oil will sink in it; I warily let fall some drops of the oil into the spirit, and they fell towards the bottom of the glass, till their descent was stopped by the horizontal surface of the alkalizate liquor. And because my design was chiefly to observe the superficial figure of a fluid, encompassed by other fluids, without touching any solid; I shall here take notice of the chief phenomena, which were produc'd of that kind.

First then, if the oily drops were but small, they seemed to the eye, exactly spherical. For the oil differing but very little in specific gravity from the spirit of wine, the drops did but just touch the surface of the subjacent alkali; and the same drops being so small, their own weight was not great enough visibly to depress them, and hinder that roundness, which the pressure of the ambient spirit, or their own viscosity, endeavoured to give them. Secondly, If an aggregate of drops were considerably bigger than the former, it would manifestly rest upon the alkalizate liquor, as upon a plain, and appear somewhat elliptical; the weight of the upper parts depressing the drops, and making the horizontal diameter somewhat longer than the transverse. Thirdly, If a yet greater proportion of oil were let fall upon the heavy liquor, it would for a pretty while, appear in the form of an imperfect hemisphere, or some other large

section

section of a sphere; the lower part being cut off by the horizontal surface of the dissolved salt. But, Fourthly, if the quantity of oil were not too great, it was pretty to observe, that tho' at first putting in, it did, perhaps, spread it self over the subjacent liquor, and lie as it were flat upon it; yet it would gradually, by the action of the surrounding fluid, concurring with its own tenacity, be raised above the surface of the liquid nitre, and be reduced to the figure, either of an hemisphere, or of a greater segment of a globe, or of an imperfect ellipsis, according to the bulk or weight of the oil. Fifthly, Tho' these globules of oil, often readily mixed, when they touched one another; yet several times we were able to make them touch without uniting, whence we have caused them so to bear against one anothers surfaces, as manifestly to press them inwards; tho' being parted, they would presently resume their former figure. But in case any of these oily portions came, by a more pressing contact, to be united, they would then alter the figures they had whilst separate, and take another suitable to the bulk of the aggregate. Sixthly, if, when a large portion of oil rested upon the saline liquors, the ambient spirit was moderately and warily agitated, it was pleasant to see the various figurations, which the convex part of the segment of the globe would be put into by the shakes, without any visible solution of continuity, or considerable motion of the whole body, which would very soon recover its former figure. But if the agitation were too strong, some portions would be quite broken off, and presently turned into little globes.

11. I tried to produce another phenomenon, by putting together, in a large vessel, with other liquors, two oils (one whereof was from turpentine) which, by reason of the oleaginous nature, wherein they agreed, might exactly mix and make a compound liquor; and, one being heavier, and the other lighter *in specie* than the water employ'd, might be again separated thereby, and include betwixt them the liquor, which had divided them. But I found that the oils, being once united, would not easily be parted; but, according to the prevalence of the lighter or heavier ingredient, in the mixture, the compound oil would almost totally, either emerge to the top of the water, or lie beneath, at the bottom of it: but some part of the oil, which was not, perhaps, all uniformly mixed, did not keep in a body with the rest; but was either separated from the mass in the form of globules, or sticking to the side of the glass, had the other part of its superficies, which was contiguous to the water, very variously figured, according as the bulk and degree of gravity of the adhering oil, and other circumstances determined.

These are some of the phenomena I observed in oil of turpentine, when environ'd only with fluids; but if it were permitted to be contiguous to the inside of the glass, and so to fasten part of it's surface to a solid, the greater portion of the surface, which remained exposed to one or both of the contiguous liquors, would, partly by their action, and partly by the gravity of the oil it self, be put into figures so various, and sometimes so extravagant, that it was much more pleasant to behold them, than it would be easy to describe them.

12. Con-

PHYSICS.

12. Confined fluids may have distinct surfaces, without having, at least in many positions, refractions differing enough, or reflections strong enough, to make the plain which separates them, obvious to the eye. Thus when the oil of tartar, or the nitrous alkali, which I employed, happened to be clear and colourless, I have, more than once, made highly rectified spirit of wine float upon it so, that in most positions, the vial seemed to contain but one uniform liquor; the plain that divided the two fluids, being unapt to be discerned but in a position, wherein the rays of light, passing from thence to the eye, fell very obliquely on it: and indeed, when there was no little dust or other feculency, swimming upon the surface of the oil of tartar; I cou'd scarce convince ordinary spectators, that the vial, in two distinct regions of it, contained two unfociable liquors.

13. We took a dissolved alkali, made of nitre and tartar, and deeply tinged it with cochineal; and that the liquors might not only be heterogeneous, but as differing in gravity and density as possible, we poured thereon a peculiar kind of oil, lighter than spirit of wine; and holding the plain, where the two liquors were contiguous, in a convenient position, in respect of the light and the eye, I observed it to make a strangely vivid reflection of the incident rays; so that this physical surface, which was flat, looked almost like that of quick-silver; and when I viewed it by the light of a candle, the bright figure of the flame was strongly reflected, almost as from a close specular body; which tempted me to suspect, that there might be something else, besides the bare smoothness of the surface of the alkalizate liquor to produce so brisk a reflection; and the rather, because I did not observe, that the remains of the same tinged alkali, which I kept in another glass, nor a portion of the same oil, which I had also by me, in a separate vial, afforded so vivid a reflection from its surface: tho' I the less wondered at this, because of the great disposition to reflect light, which I had formerly observed in the fore-mentioned oil, when joyned with other liquors. And looking on this fluid, as a body which, tho' it hath all the necessary qualities of an oil, does, in regard of its origin, and some properties I have found in it, differ from common chymical oils; I was invited the more to observe its phenomena, with regard to reflection: and I found, 1. That the confining plain, between the tinged alkali and this liquor, did not appear red, it self, nor communicate that colour to the image of the flame of a candle, reflected from it. 2. That when I warily shook the containing vial, the upper liquor would be reduced into a seeming froth, consisting of a great number of imperfectly globular bodies, that, after a while, would make a kind of rude physical plain; which, tho' neither horizontal, nor sensibly smooth, would, at its upper superficies, send back the incident light with more briskness, than one could expect. And when the seeming froth consisted of smaller particles, these, when they were of a certain size, and conveniently placed, with regard to the flame of the candle and the eye, would, reflect the incident light so many ways,

and so visibly, that they seemed, for multitude and splendor, like little sparkling corpuscles of polished silver. Thirdly, that tho' pure spirit of wine be so thin a liquor, and our oil so light, as to swim upon it; yet I found the confining surface very strongly reflective. I have also found, that some other essential oils, and particularly an unsophisticated one of lemons, did, with our tinged alkali, afford most of the same phenomena, but not so brisk a reflection.

14. In cold weather we took essential oil of aniseeds, whose property it is to coagulate in such weather, and having, in a gentle warmth, brought it to be fluid, we poured it into a slender vial more than half filled with common water, which had been, also, a little warmed, that the oil might not be too hastily reduced to its former state. This oil being lighter than so much water, and being poured on in a convenient quantity, had its upper surface somewhat concave, as that of the water was; but the lower surface, surrounded by the water, was very convex, appearing almost of the figure of a great portion of a sphere. This being done, the vial was stopped, and suffered to rest, for some time, in a cold place; by which means, the water continuing fluid as before, the oil was found coagulated in a form, approaching to that it had whilst in a fluid state. It is worth observing how great a difference there was between the dull reflection it made, when coagulated, and the fine one it had made, whilst a liquor.

15. Having observed, that quick-silver, and rectified *Oleum Petra*, are, the former of them the heaviest, and the latter the lightest of all the visible fluids yet known to me; I put some distilled quick-silver into a small vial, and held it in such a posture, that the incident light was strongly reflected to my eye; I then slowly put to it some *Petrelæum*, which being well rectified was very clear; and observed, that as this liquor covered the quick-silver, there was at the imaginary plain, where they both joined, a brisker reflection, than the quick-silver alone had given before. On this occasion it will not be amiss to take notice, that either the surface of the air itself, as thin and yielding a fluid as it is, or the surface of a solid, contiguous to included air, or some interposed subtile matter, may reflect the incident rays of light, more strongly, than most men would expect. A curious person having one day brought me two pieces of a solid, transparent body, which he had casually found, in one of which there was a pearl, large, round, and orient; and in the other one less perfect; one of them was opened, when that which had appeared a pearl, was found to be but a cavity, which contained no grosser a substance than air. And I have by me, a well-shaped piece of thick glass, with an aerial bubble in the middle, which by some qualities, particularly its pear-like shape, and vivid reflection, well resembles a fair, tho' not orient pearl. But in such observations, the position of the eye, and that wherein the body receives the rays of light, may be very considerable. For I have a small stone, that being laid flat upon one's hand, or a piece of paper, and looked on directly downwards, ap-

PHYSICS.

pears almost like a piece of common glass, and is transparent ; but if the eye be so placed, that the incident rays of light, by whose reflection it is seen, fall with a convenient degree of obliquity upon the stone, it makes an exceeding pretty shew ; sometimes appearing like a fine opal, and sometimes not very unlike an orient pearl.

16. Having prepared a competent quantity of a resinous substance, which looked like high-coloured amber, but was easy to melt ; we put it into a deep round glass, with a wide mouth, and held it by the fire-side, till it was brought into a fluid state ; then we transferred it into a pneumatical receiver, where we presumed, that this temporary liquor, would disclose aerial bubbles, when the pressure of the air was withdrawn from it ; and, accordingly, having caused the air to be pumped out by degrees, we found numerous bubbles appear at the top of the liquor, where they made a great froth, many of them being, by reason of the viscosity of the fluid, very large, and several of them adorned with the colours of the rain-bow. I caused the pumping to be continued, that those bubbles, which had most common air in them, and which, therefore, rise first, might get to the top, and the subsequent bubbles might meet with more resistance from the liquor still tending to grow cold, and so be the more expanded, and yet kept from emerging, by the concretion of the resinous substance ; and answerably to this, we found, that when the substance had resumed its consistent form, there were intercepted, between the upper and lower surfaces of it, some bubbles, which were not small, yet made a considerable reflection ; notwithstanding the small quantity of the grosser particles of the air, that may be supposed to be contained in bubbles so very much expanded.

17. It is taken for granted, that the falling drops of rain are spherical, yet their descent is so swift, that I fear, this is rather supposed, than observed ; which will be more questionable, if hail be but rain frozen, in its passage through the air. For it is evident, that the grains of hail are, frequently, of other figures, than truly orbicular. But the surface of water may have different figures, accordingly, as it is totally encompassed with heterogeneous fluids, or as it is only in some places, contiguous to one or more of them. In the former case, we found it not so easy to make an observation, because, we know not of any two liquors, (I except mercury) which will not mix either with one another, or with water. We, therefore, cautiously conveyed into chymical oil of cloves, some portions of common water of different sizes ; taking care, that they might not touch one another ; by which means, the oil being transparent, and yet somewhat coloured, it was easy to observe, that the smaller portions of water, were so near totally invironed with the oil, as to be reduced into almost perfect globes ; those portions, which were somewhat bigger, would be of a figure somewhat approaching to that of an ellipsis, and those, which were yet larger, tho' they seemed to be sunk almost totally beneath the oil, yet they held to it by a small portion of themselves, whose surface was easily distinguish-

able

able from that of the oil. These larger portions of immersed water, being almost wholly invironed with the other liquor, were by it reduced into a round figure, which was ordinarily somewhat elliptical; but more depressed in the middle, than that figure.

18. Having into a slender pipe put a little oil of cloves, and upon this some oil of turpentine, so that the water might, both above and beneath, be touched by heterogeneous liquors; I observed, not the oil of cloves to be very manifestly tumid at the top, nor the lower surface of the oil of turpentine to be very convex; from whence 'tis easy to determine, the figure of the cylindrical portion of water, intercepted between the two oils.

19. I took oil of aniseeds, thawed by a gentle warmth, and common water, and having put them together, in a conveniently-shaped glass, they were suffered to stand in a cold place, till the oil was coagulated; which done, it was parted from the water, and, by the roughness of its superficies, manifested, that, when its parts were no longer agitated, and kept easily moveable, by the subtil permeating matter, or whatever other agent or cause it was, to which it owed its fluidity, the contiguous water grew unable to inflect, or otherwise place them after the manner requisite to constitute a smooth surface. And what happened to that part of the oil's surface, which was touched by the water, happened also to that, which was contiguous to the air; only the asperity of the latter surface differ'd from the other; which, whether it were an accidental, or constant phenomenon, farther trial must determine. But I have often observed, that the upper surface of oil of aniseeds, when this liquor comes to be coagulated by the cold air, was far enough from smooth; being render'd very rugged by many flaky particles, some of which lay with their broad, and others, with their edged parts upwards.

20. An inequality and ruggedness of superficies I have also observed in water, when, having covered it with chymical oil of juniper, and exposed it in very cold weather; for, though the oil continued fluid, yet the water, being frozen, had no longer a smooth superficies, as whilst, in its liquid state, it was contiguous to the oil. And the like inequality, or rather a greater, we observed in the surface of water frozen, which had chymical oil of turpentine swimming over it; yet a greater roughness may be often observed in the surfaces of several liquors, which abound with water, when those liquors, being frozen, their surfaces have an immediate contact with the air. Having purposely caused a strong and blood-red decoction of wood-foot to be exposed in a large glass, in a very cold night; I found in the morning, a cake of ice, which was curiously figured, being full of large flakes, shaped almost like the broad blades of daggers, and neatly fringed at the edges. But these figures seem to be, as it were, imbossed; being, both to the eye and the touch, raised above the horizontal plain of the other ice.

21. I have sometimes observed the like phenomenon in one and the same liquor; and particularly not long since, in frosty weather, in a vial,

PHYSICS. where I had long kept oil of vitriol, I perceived, that the cold had reduced far the greatest part of the menstruum into a consistent mass, whose upper surface was very rugged, and oddly figured, though it lay covered, all over, with a pretty deal of a high coloured liquor, which was not frozen, or coagulated, nor seemed disposed to be so, at least in that degree of cold.

23. This may be also observed in the best sort of what the chymists call *Regulus Martis stellatus*, where the figure of a star, or one somewhat like that of the decoction of foot, lately mentioned, will frequently appear imbossed upon the upper superficies of the *regulus*; and such a raised figure I have seen on a mass of *regulus*, made of antimony, without iron. But if to those two bodies, copper also be skilfully added, the superficies will be often adorned with new figures, according to the circumstances; tho' the most usual I took notice of was that of a net, which seemed to cover the surface of the compounded *regulus*. This, however, is not so constant, but that I have by me a mass of a conical figure, consisting of two very contiguous, but easily separable parts, the lowermost whereof, which abounds more in metal, hath its upper surface covered with round protuberances, in shape and bigness, like small pease cut in two; and these are so really imbossed, and elevated above the rest of the superficies, that the other part of the cone, which is of a more scorious nature, has, in its lower surface, which exactly fits the upper of the *regulus*, cavities, for number, shape, and size, answering to the protuberances; which argues, that the *regulus* cooled first, with that inequality of surface, we have described; and that the lighter, and more drossy substance, continuing longer fluid, had thereby an opportunity to accommodate itself to the superficial figure of the *regulus*, on which it first rested, and afterwards coagulated.



THE
ATMOSPHERES
OF
CONSISTENT BODIES.

S E C T. I.

THAT fluids should send out exhalations, will, I presume, be readily granted, especially considering the sensible evaporation of water, wine, &c. and the loose contexture of parts necessary to compose soft bodies; but that hard, and ponderous substances, likewise, emit steams will, perhaps, require to be proved. But though we might *à priori*, both from the *Epicurean* and *Cartesian* philosophy, shew, that consistent bodies are exhalable; it will be more satisfactory and useful to do it *à posteriori*, by particular experiments and examples.

That a dry and consistent form does not infer an indisposition to yield effluvia, is evident in all the aromatics, and perfumes, but more especially in camphire, and such volatile salts, as are obtained from hartshorn, blood, &c. for these are so fugitive, that I have had a lump of volatile salt fly away, without leaving a grain behind; and I found, that a small piece of camphire would, in a few hours, suffer a visible loss of weight, by the avolation of scented corpuscles; tho' the experiment was made in a north window, and in the winter season. But if instances are required from bodies of a close and solid texture, I have found, that many electrical bodies, such as amber, rosin, brimstone, &c. when they are well rubbed, part with numerous corpuscles; and the common explanation of the attraction of such bodies, supposes the emission of corporeal particles. I have found several fruits, &c. even in winter, grow daily lighter in the scales, wherein I kept them, noting their decrease of weight; but to shew, how considerable an evaporation is made from wood, I caused a thin cup, that would hold a pint, to be turned, of a sort of it that was not very close, from which, in the winter, there was so quick and plentiful an evaporation, that I found it no easy matter to counterpoise it; for whilst grains were putting into the opposite

*Aromatics, and
bodies of a loose
texture, exhalable.*

*And those of a
close and solid
texture.*

PHYSICS.

lite scale, the great avolation of invisible steams would make the scale that held it, sensibly too light. For farther satisfaction, I ordered a bowl, about the same bigness with the former, to be made of well-seasoned wood, which, being suspended, in my chamber, quickly began to lose of its weight; and though the whole vessel weigh'd but an ounce and three quarters, yet from ten a-clock in the morning to ten at night, it lost about forty grains.* And it were easy to multiply instances of the continual exhalation of steams from vegetable and animal substances; but since those substances are the most unlikely to afford effluvia, that are either very cold, or very ponderous; very solid and hard, or very fixed; if I can shew, that these qualifications cannot keep a body from emitting steams, I shall have made it probable, that all sorts of bodies may afford them. And first, I have not only found eggs, in a very sharp winter, to grow sensibly lighter, but having counterpoised a convenient quantity of ice in an exact balance, and exposed it to the cold air of a frosty night, that the evaporations should be from ice, and not from water, I found, the next morning, its weight considerably diminished; and this experiment I made with the like success in more than one winter, and more than one place.

As also cold bodies.

Various exhalations raised, by means of fire, from solid bodies.

But, by the way, in explaining some occult qualities, such exhalations as are raised by means of fire, may be taken into consideration. Now fire is able to put the parts of bodies into so violent a motion, that except gold, glass, and a very few more, there are none so fixed and solid, but it will dissipate, either totally, or in part. Not only lead and tin, but much harder bodies emit plentiful and noxious steams; and there are some kinds of iron, which our smiths call cold-share iron, whose smell, whilst red hot, is intolerably strong and rank, in the working. And without being brought to fusion, not only brass and copper will become strongly scented, but common iron also; as is evident by the smell of many iron stoves.

Very ponderous bodies yield effluvia.

To proceed to ponderous bodies; if we allow, that the magnetical operations of the load-stone, for instance, are performed by particles issuing from it; this will serve for an instance to our present purpose, since I have hydrostatically found, that some load-stones have double the weight of flints, or other stones of the same bulk. And stone-cutters will inform us, that black marble, and some other heavy stones, yield a very sensible smell in polishing; and it will be granted, that odours are not diffused without corporeal exhalations. Having procured some of those, which pass among the vulgar for thunder-stones, I could, by rubbing them, excite a strong sulphureous scent. I have also made a certain

* It appears very probable, from an observation of Dr. Lister, that odoriferous bodies spend their very substance in effluvia. He found great numbers of stones, which lay in several drawers, made of *Ba: badoes* cedar, were thick covered over with a liquid resin, like *Venice* turpentine, tho' no manner of exudation appeared in any part of the cabinet. Whence, says the Dr. the whole body of the turpentine of the cedar wood, must have been carried into the air, and floating therein, be again condensed, in its own form, upon these stones. *Philos. Transf.* N^o. 110. p. 224.

mineral

mineral mass, almost as ponderous as a metal, emit more strongly scented exhalations, than I could well endure. And having once made a chymical mixture of a metalline body, and coagulated mercury, it was so disposed to part with corporeal effluvia, that a person, who practised physick, begged a little of it for some patients, troubled with distempers in the eyes; and afterwards affirmed, that it very happily cured them, by being worn in a ring on the finger, or as an *Appensum* near the diseased part. If we make a *Vitrum Saturni*, with a large quantity of *Minium* in proportion to the sand or crystal, which it helps to fuse, we shall have a glass exceeding ponderous, and yet not destitute of electricity. And having sometimes caused brass to be turned, after the manner of wood, to try, whether so great a concussion would not throw off steams, that might be smelt, it answered my expectation; and a workman, who used to turn very great quantities of brass, informed me, that the scent of it in the lath, was sometimes so strong, as to be very offensive to persons un-used to it.

I proceed now to the effluvia of solid and hard bodies: and here I may be allowed to instance in electrical ones, because they are acknowledged to operate by substantial effluvia. Now among these, I have observed many of so close a texture, that neither *Aqua fortis* it self, nor spirit of salt, would work upon them; and to be so hard, as to strike fire, like flints. Of the former sort I have found several gems, and even cornelian it self; rock crystal also, though it hath an attractive virtue, is yet so hard, as to strike fire, rather better than ordinary flints: and though diamonds are the hardest bodies we know, yet frequent experience has assured me, that even these, are very manifestly electrical. There is a sort of concretions, very well known in several parts of *Italy*, by the name of *Cugoli*, and much used by the glass-men. These are very, hard, and yet by rubbing them one against the other, they afford a very strong smell. To which we may add, that strong scents are produced by the attrition of *Calculi humani*, iron, marcasites, pyrites, &c. whence it appears, that bodies, capable of being the source of corporeal effluvia, may be, at once, very solid, and very ponderous. It, therefore, only remains to shew, that even fixedness in bodies is not incompatible with their disposition to yield exhalations. The *Regulus* of antimony, and also its glass, though they must have endured fusion, to attain their respective forms; yet they will, without heat, communicate emetic and purgative expirations to liquors: and several electrical bodies are very fixed in the fire; particularly crystal will endure several ignitions, and extinctions in water, without being truly calcined. But because the antimonial bodies just mentioned will, after a while, fly away in a strong fire; and because the effluvia of crystal are not so sensible, as those which immediately affect our eyes or nostrils; I will here subjoin an instance, which will render others needless: for, tho' glass is able to endure so vehement a fire, yet I quickly found, that by rubbing

Very solid, hard,
and ponderous
bodies yield them.

And even such as
are fixed.

PHYSICS. two solid pieces of it, against one another, they would not only yield a sensible, but a strong offensive odour.

*The atmospheres
of bodies excited
by gentle heat.*

And as the sun is the great agent of nature, in the planetary world; and since, during the summer, and especially at noon, and in southern climates, his heat makes many bodies have little atmospheres, that we cannot constantly so well discern; we may very well ascribe atmospheres to such bodies, as have them from the sun's influence; and allow the like to such other bodies, as will perform the things usually ascribed to effluvia, when yet they are excited but by an external heat, which exceeds not that of the clear sun. Of these two sorts, I shall give but two examples.

To shew, that the particular and usual manner of exciting electrical bodies, by rubbing them, is not always necessary; I took a large piece of good amber, and having in a summer's morning, whilst the air was yet cool, tryed, that it would not, without being excited, attract a light body, I removed it into the sun-beams, till they had made it moderately hot; and then found, it had acquired an attractive virtue; and that not only in one particular place, as when it is excited by rubbing, but in several distant places at once; so that even in our climate, a solid body may quickly acquire an atmosphere by the presence of the sun, and that long before the warmest part of the day. I also took a little small thick vessel of glass, and held it near the fire, till it had got a convenient degree of heat, whereby it became attractive, as that of the sun's heat had rendered the amber. Hence it seems deducible, that many consistent bodies, whether animal, vegetable, or mineral, may emit effluvia; and that even such as are solid may respectively have their little

Many more bodies may emit effluvia, and have their atmospheres, than is usually imagin'd.

atmospheres. And several things induce me to believe, that there are many more bodies of the like nature. For, very few have had the curiosity to make use of nice scales, to examine the expirations of inanimate bodies; but if they shall hereafter, they will doubtless find, that some bodies, not yet known to yield exhalations, afford them; and that many others part with far more than is usually imagined. Who would have thought, that so extremely a cold body as a solid piece of ice, should plentifully evaporate in the cold air of a freezing night; or that a piece of wood, which had long lain in the house, and was light enough to be conveniently hung, for a long time, at a very exact balance, should, in less than a minute, breathe out steams enough to make the scales manifestly turn, and that in the winter? But, supposing such trials, made with good instruments for weighing; though it is certain, that in case the exposed body grows lighter, something exhales from it; yet it will not follow, if no diminution of weight be discovered by the instrument, that nothing corporeal recedes from it. For though the load-stone be concluded to have constantly about it a great multitude of magnetical effluvia, which may be called its atmosphere; yet it hath not been observed to lose of its weight by the avolation of so many corpuscles; and though good amber-grease be constantly surrounded by a large atmosphere, the waste of it is surprizingly small. If it be said,

Bodies may exhale, without manifesting it by a loss of weight.

that

that in length of time, a decrease of weight may appear in bodies, that discover none in a few hours or days; the objection, if granted, does not affect our doctrine: it is sufficient for us to have proved, that the effluvia of some bodies may be subtil enough, not to make those bodies, by their avolation, appear lighter in short statical trials. And for ought we know, the decrease of bodies in statical experiments, long continued, may be greater, than even nice scales will discover; for how are we sure, that the weights themselves, which are commonly made of brass, may not, in tract of time, suffer a little diminution, as well as the bodies counterpoised by them? And no man, I think, has yet tried, whether glass, and even gold, may not in length of time, lose of their weight; which in case they should do, it would not be easily discovered, unless we had bodies that were perfectly fixed; by comparing them whereto we might be better assisted, than by comparing them with brass weights, or the like, which, being themselves less fixed, will lose more than gold or glass.

Lastly, there may be several other ways, besides the statical, of discovering the effluvia of solid bodies; and consequently of shewing it unsafe to conclude, that because their operation is not constant or manifest, such bodies never emit any effluvia at all; and so are unable to work, by their means, on any other body, though never so well disposed to receive their action. And this I the rather observe, because my principal design was here to illustrate the doctrine of occult qualities. It may conduce to explain several of them, to know that some particular bodies emit effluvia, though perhaps they do it not constantly and uniformly; and tho' perhaps too, they appear not to have emitted any at all, if examin'd after the same manner, with other exhalable bodies; but only may be made to emit them by some determinate operation on another single body, or small number of bodies. Without trial, one would not think, that from glass there could, by rubbing, be obtained such steams, as to offend the nostrils. Nor should we easily believe, if experience did not assure us, that a diamond will, by a little rubbing, be made to part with electrical effluvia. Nay, I once had a diamond unpolish'd, uncut, and not much bigger than a large pea, whose electrical virtue was easily excited, by barely passing my fingers over it to wipe it: and if, as soon as I had taken it out of my pocket, I applied an hair to it, tho' I touched not the stone with my fingers, that I might be sure not to rub it, that hair would be attracted, at some distance, for several times successively; especially by one of the sides of the stone: and tho' this excitation of the diamond seemed to proceed only from the warmth it had acquired in my pocket; yet I did not find this warmth, tho' it seemed not to be altered, had always the same effect on it; but the wiping it with my finger failed not to excite it. Something like this uncertainty I always observed in another diamond, which was much nobler, and very well polished; and also in a small ruby, which sometimes would prove considerably electrical, without be-

Other ways besides the statical, of discovering the effluvia of solid bodies.

PHYSICS.

ing rubbed, when I but wore the ring it belonged to, on my finger; and sometimes, again, it seemed to have lost that virtue, without my knowing whence such a change should proceed. I have seen a stone, which I should have judged to be agate, and consequently, have thought, that it could not communicate medicinal effluvia, fitted to stop bleeding, if the wearer of it had not been subject thereto; and often cured both himself and others, by wearing this stone about the neck; and if he left it off, as sometimes he did for trial-sake, that would in a few days return. And it would probably have never been suspected, that so ponderous and solid a body as the load-stone, should be surrounded by an atmosphere, if iron had been a scarce mineral; and had not chanced to have been placed near it. And since solid bodies may have constant atmospheres about them, and yet not discover, that they have them, but by their operation upon one particular body, or those few which participate of it; and since there are, already, very different ways, whereby bodies may appear exhalable; it is not unlikely, that more bodies will, by degrees, be found to emit effluvia, as more ways of discovering that they do so, shall, either by chance or industry, be brought to light.



THE

THE
Nature, Properties, and Effects
 OF
 EFFLUVIA.

S E C T. I.

WHETHER we suppose, with the ancient and modern atomists, that all sensible bodies are made up of indivisible corpuscles ; or whether, with *Aristotle* and the *Cartesians*, we grant matter, like quantity, to be indefinitely divisible ; the effluvia of bodies may consist of particles extremely small. According to the opinion of *Aristotle* and *Descartes*, no stop can be put to the subdivision of matter : and though the *Epicurean* hypothesis will have it terminate in certain solid corpuscles, which, for their not being further divisible, are called atoms ; yet the assertors of these, justly think themselves injured, when they are charged with taking the motes, that float in the sun-beams, for their atoms ; since, according to these philosophers, one of those little grains of dust, that is visible, only when it plays in the sun-beams, may be composed of a multitude of atoms, and exceed many thousands of them in bulk. This the learned *Gassendus* makes probable, by the instance of a small mite ; which, tho' scarce distinctly visible to the naked eye ; yet in a microscope appears to be a compleat animal, furnished with all necessary parts : and, I have often, in cheese-mites, very distinctly seen the hair growing upon their legs. Thus much may serve to shew, that the wonderful minuteness, I shall hereafter ascribe to effluvia, is not inconsistent with the most received theories of naturalists : otherwise, the proofs I mean to employ, must be taken, not *à priori*, but *à posteriori*.

Now, the experiments and observations, to be used on this occasion, will be chiefly such as are referable to the following heads.

1. The strange extensibility of some bodies, whilst yet their parts remain tangible.
2. The multitude of visible corpuscles, that may be afforded by a small portion of matter.

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PHYSICS.

3. The minuteness of the pores at which the effluvia of some bodies will enter.

4. The small decrease of bulk, or weight, that a body may suffer by the loss of numerous effluvia.

5. The great quantity of space that may, as to sense, be filled by a small quantity of rarified matter.

The strange subtilty of effluvia, argued from the fineness of silver wire.

Among many things that are gross enough to be the objects of touch, and to be managed with our hands, there are some which may help us to conceive a wonderful minuteness in the small parts they consist of. I procured silver, whose ductility is very much inferior to that of gold, to be drawn out to so slender a wire, that when it was accurately measured, nine yards thereof weighed but about a grain, in a very tender balance. And since experience informs us, that half an *English* inch may, by diagonal lines, be divided into 100 parts, capable of being easily distinguished for mechanical uses; it follows, that a grain of this silver wire may be divided into 64,800 parts; and yet each of these will be a true metalline cylinder, which we may very well conceive to consist of a multitude of minuter parts. For, tho' I cou'd procure no gilt wire near so slender as our silver wire; yet a grain of some I had by me, was fourteen feet long: at which rate, an ounce wou'd reach about a mile. And if we suppose the gilt wire, as in probability it might have been drawn, as slender as the silver wire; the instance will be still far more considerable: for in this case, each of those little cylinders, of which 64,800 go to make up one grain, will have a superficial area, which, except at the bases, is cover'd with a case of gold, that is not only separable from it by a mental operation, but, perhaps, also by a chymical one. For, I remember, that from very slender gilt wire, tho' I could procure none so slender as this of mere silver, I more than once got out the silver; so that the golden films, whilst they were in a liquor that plump'd them up, seem'd to be solid wires of gold; but when the liquor was withdrawn, they appeared oblong and extremely thin double membranes of the metal; which, with a fine instrument, might have been ripp'd open, display'd, and made capable of further divisions and subdivisions. But tho' each of the little silver cylinders, just mention'd, must not only have its little area, but its solidity; yet I saw no reason to doubt, that it might be very possible to have drawn the same quantity of metal to a much greater length; since even an animal substance is capable of being brought to a slenderness much surpassing that of our wire. An ingenious gentlewoman of my acquaintance, who kept silk-worms, had once the curiosity to draw out one of the oval cases they spin, into all the silken wire it was made up of; which appear'd in measure, to be much above 300 yards, yet weigh'd but two grains and a half; so that each cylindrical grain of silk may well be reckon'd to be, at least, 120 yards long.

Silken threads.

Leaf of gold.

We took six leaves of beaten gold, and singly measuring them with a ruler, purposely made for nice experiments, we found them to have a greater

ter equality in dimensions, and to be nearer true squares than could be well expected: the side of the square was, in each of them, exactly three inches and a quarter; which number being reduced to a decimal fraction, viz. 3.25 and multiply'd by itself, affords 10.5625 for the area of the six leaves. These being carefully weigh'd, in a pair of tender scales, amounted, all of them, to one grain and a quarter; and so one grain of this leaf-gold was extended to somewhat above 50 inches; which differ'd, but about a fifth part, from an experiment of the like nature that I made, many years ago, in a pair of exact scales: and so small a difference may very well be imputed to that of the pains and diligence of the gold-beaters, who do not always work with equal strength and skill; nor upon equally fine and ductile gold. Now, supposing an inch, divided into an hundred sensible parts, to be applied to each side of a square inch of this leaf-gold; 'tis manifest, that by fine parallel lines, drawn between all the opposite points, a grain of gold must be divisible into five hundred thousand very minute squares, but yet discernable by a sharp eye. And if we suppose the inch divided into two hundred parts; the number of the squares, into which a single grain is capable of being divided, will amount to no less than two millions.

There is yet another way to shew the great divisibility of gold. A re-
finer, with whom I used to deal, informed me, that to an ounce of silver he commonly allow'd eight grains of gold, when it was to be drawn into well-gilt wire, as slender as a hair; but that if it were to be more slightly gilt, six grains would serve the turn. He also shewed me a fair cylindrical bar of silver, as it was at first gilt, whereon the leaf-gold that overlaid the surface did not appear to be, by odds, so thick as fine *Venetian* paper; yet comparing this with gilt wire, the wire appear'd to be the better gilt of the two; possibly because the gold, in passing thro' the various holes in the making, was, by the sides of them, not only extended, but polish'd; which made it look more vividly than the unpolish'd leaves that gilt the ingot. So that, if we suppose an ounce of the gilt wire lately mention'd, to have been gilt with six grains of leaf-gold, it will appear, by an easy calculation, that, at this rate, one ounce of gold, employ'd in gilding wire of that fineness, would reach between ninety and a hundred miles. But if we further suppose, that the slender silver wire, first mention'd, were gilt; tho' we should allow it to have not six, but eight grains of leaf-gold to an ounce of silver; it must be acknowledg'd, that an hollow cylinder of gold, weighing but eight grains, may be stretch'd so as to reach as far as sixty times its weight of silver wire, which it covers; and consequently, a grain of that wire having been found to be 27 feet long, an ounce of gold would reach 155 miles, and above an half. And if we yet further suppose this hollow cylinder of gold to be slit along, and cut into as slender lists as possible; we cannot deny that the gold may be made to reach a stupendous length.

To this view of the minuteness of tangible objects, 'twill be proper to subjoin some instances of the smallness of such as still continue visible.

The small quantity of gold employ'd to gild silver wire.

PHYSICS.

*The rarification
of water, turn'd
into vapour.*

fible. But as these corpuscles are, singly, too little to have any common measure applied to any of them; we must estimate their minuteness by the number of those into which a small portion or fragment of matter may be actually divided; the multitude of these, being afforded by so inconsiderable a quantity of matter, sufficiently declaring that each of them, in particular, must be surprizingly little.

Water, tho' granted to consist of gross particles, in comparison of the spirituous and odoriferous ones of several other liquors, as pure spirit of wine, &c. yet to shew that a small quantity of it may be dispersed into a multitude of manifestly visible corpuscles, I more than once tried the rarification of it into vapours, by help of an æolipile, where-with, when I made the experiment the last time, the event proved as follows:

We put an ounce of common water into an æolipile, and having set it upon a chafing-dish of coals, we observed the time when the stream of vapour began to be manifest. This stream was for a considerable time impetuous, as appear'd by the noise it made, which would be much increas'd, if we applied to it, at a convenient distance, a kindled brand, whereof it would blow up the fire very vehemently. The stream continued for about a quarter of an hour, but afterwards the wind had pauses and gusts for two or three minutes, before it quite ceas'd. And by reason of the shape of the æolipile, a great portion of the vapours condens'd in the upper part of it, and fell down in drops; so that, supposing they also had come out in the form of wind, and the blast had not been intermitted towards the latter end, I guess'd it might have continued, uninterruptedly, for 18 or 20 minutes. And by applying a measure to the smoke, that came out very visible, in a form almost conical, where it seem'd to have an inch or more in diameter; it appear'd to be distant from the orifice of the æolipile, about 20 inches, and five or six inches beyond that, tho' it were spread so much as to have four or five inches in diameter, yet the irregular coherent clouds were manifestly conspicuous.

*The rarification
of fœw, turn'd
to flame.*

After the rarification of water turn'd to a vapour, we may consider that of fœw, when 'tis turn'd into flame.

Having often burn'd spirit of wine, and also oil, in glass lamps, so made, that the surface of the liquors still continued circular; 'twas easy to observe, how little the liquor would subside by the waste that was made of it in about half a quarter of an hour. Yet, if we consider, that the naked eye, after some exercise, may, as I have often try'd, discern the motions of a pendulum that swings fast enough to divide a single minute into 240 parts; and consequently half a quarter of an hour into 1800 parts; if we also consider into how many parts of the time employ'd by a pendulum, the vibrations, slow enough to be discernible to the eye, maybe, mentally, subdivided; and if we further consider, that, without intermission, the oil is prey'd upon by an actual flame, and that the particles of it continually furnish a considerable stream of shining matter, which, with a strange celerity, is always flying away; we may very well

well conceive that those parts of flame, into which the oil is turn'd, are surprizingly minute; since, tho' the wasting of the oil is in its progress too slow to be perceiv'd by the eye; yet 'tis certain, there is a continual decrease of its depth, it's physical surfaces being continually and successively attenuated and turned into flame*. And the strange subtilty of the corpuscles of flame might be more strongly argued, if we we should suppose, that, instead of common oil, the flame were nourish'd, as 'tis possible, by a fewel much more compact and durable.

Having, in a pair of tender scales, carefully weigh'd out half a grain of gun-powder, we laid it on a tile, and wheml'd over it a vessel of glass, Gun-powder in- to smoke, and flame. with a brass plate to cover the upper orifice of it; then having fired the gun-powder, we observed, that the smoke of it darken'd, and, as to sense, fill'd the whole cavity of the glass, tho' its basis were eight inches, its perpendicular height above twenty, and its figure far more capacious than if it were conical. And this smoke, not containing itself within the vessel, issued out at two or three little interstices, that were purposely left between the orifice of the vessel, and the plate that lay upon it. This cover we then remov'd, to observe how long the smoke would continue to ascend; which we found it would do for about half a quarter of an hour; and during near half that time, the smoke, continually ascending, seem'd to be, at its going out, of the same diameter with the orifice at which it issued; and it wou'd ascend sometimes a foot, sometimes half a yard, sometimes two feet, or more, into the air, before it dispers'd and vanish'd into it.

Now, considering that the cavity of this round orifice was two inches in diameter, how many myriads of visible corpuscles, may we easily conceive, throng'd out at so large an out-let, in the time abovemention'd; since they were continually thrusting one another forwards? And into so many visible particles of smoke, must we admit, that the half grain of powder was shatter'd; besides those multitudes, which, having been turn'd into actual flame, may, probably, be suppos'd to have suffer'd a comminution that render'd them invisible. And to shew that the number of these small particles was exceeding great, I caus'd the glass to be filled with common water, and found it to contain 22 pints; and causing one of those measures of that fluid to be weigh'd, it came so near sixteen ounces, that the computation of the whole water amounted to, at least, 160,000 grains, and consequently 320,000 half grains. To which, if we add, that this gun-powder would readily sink to the bottom of water, as being *in specie*, probably, twice as heavy; we may guess the space, to which the smoke reach'd, exceeded 500,000 times that which contain'd the unfired powder; and this, tho' the smoke being confin'd in the vessel, was thereby kept from diffusing itself so far as, by its streaming out, it shou'd seem it wou'd have done.

* An inch of candle, when converted into light, is, according to Dr. Nieuwentyt's calculation, in his *Religious Philosopher*, divided into 269,617,040 parts.

PHYSICS.

The wonderful
minuteness of the
parts in the first
rudiments of a
mite.

To these instances, from inanimate bodies, I shall add one taken from animals. Those, who have, from time to time, open'd eggs that have been brooded upon by a hen, cannot but have observed, how small a proportion the chick bears to the bulk of the whole egg; when that which Dr. Harvey calls the *Punctum saliens*, discloses the motion of the heart, and the colour of the blood; and that even about the seventh or eighth day, the whole chick, now visibly form'd, bears no great proportion to the whole egg, which is to be supply it with aliment, not only for its nourishment, but speedy growth for many days after.

Now, having several times found, that cheese-mites themselves are generated of eggs; if we conceive that in these eggs, as in ordinary ones, the animal, at its first formation, bears but a small proportion to the bulk of the whole egg; the remaining part being to suffice for the food and growth of the embryo, probably for a considerable time; (since, if an ingenious person, whom I desired to watch them, did not mis-inform me, they use to be about ten or twelve days in hatching;) and as this whole egg itself will be allowed to be but little, with regard to the mite it came from; how extremely and unimaginably minute then, may we suppose those parts to be, that make up the alimental liquors, and even the spirits, that, passing through the nerves, serve to move the limbs and organs of sense, of but, as it were, the model of such an animal, as when it rests, wou'd not itself be visible to the naked eye?

A subtle division of a grain of copper.

We carefully weigh'd, in a pair of tender scales, one grain of copper filings, and made a solution thereof in the spirit of sal-armoniac; having found by former trials, that this menstruum wou'd give a far deeper blue colour, than either *Aqua fortis*, or *Aqua regia*. This liquor, of which we used a large portion, that all the copper might be thoroughly dissolved, we put into a tall cylindrical glass, about four inches in diameter, and, by degrees, pour'd to it of distill'd water, which is more proper, in this case, than common water, till we had almost fill'd the glass, and saw the colour grow somewhat pale; and then we warily pour'd this liquor into a conical glass, that it might be the more easy to fill the vessel several times to the same height. This conical glass we filled to a certain mark, four times successively; weighing it and the liquor too, as often, in a pair of excellent scales, purposely made for statical experiments; and which, tho' strong, wou'd, when not too much loaden, turn with about one grain. These several weights of the glass, together with the contain'd liquor, we added together; and then carefully weighing the empty glass again, deducted four times its weight from the sum, and thereby found the weight of the liquor alone to be 28,534 grains; so that a grain of copper, which is not half so heavy in *specie* as fine gold, communicated a tincture to 28,534 times its own weight.

But as the design of my experiment was to shew into what a number of parts one grain of copper might be divided; this multitude of parts must be estimated by the proportion, not so much in weight, as in bulk,
of

of the tinging metal to the tinged liquor; and consequently, since hydrostatical trials have informed me, that the weight of copper to the weight of water, of the same bulk, is nearly, as nine to one; a grain of copper is in bigness, but the ninth part of as much water as weighs a grain; and so our number of the grains of ting'd water must be multiplied by nine, to give us the proportion between the tinging and tinged bodies; that is, a single grain of copper gave a blueness to above 256,806 parts of limpid water, each of them as big as it. Which, tho' it may seem scarce credible, yet I thought fit to prosecute the experiment farther, by pouring all the liquor out of the tall cylindrical glass into another clean vessel, whence filling the conical glass twice, and emptying it as often into the same cylindrical glass, the third time I fill'd the conical glass with colourless distill'd water, and pouring that also into the cylindrical glass, we yet found the mix'd liquor to have a manifest blueness. And, lastly, throwing away what was in the cylindrical glass, we pour'd into it, out of the same conical glass, equal parts of distill'd colourless water, and of the ting'd liquor, we had formerly set apart in the clean vessel, and found, that tho' the colour were very faint, yet an attentive eye could easily discern it to be bluish; and so it was judg'd by a stranger who was brought in to look upon it, and desired to say of what colour he thought it: whence it appears, that one grain of copper was able to impart a colour to above double the former quantity of water.

This experiment I have been the more particular in relating, both because it is new, and because, without circumstances, it wou'd seem as incredible as 'tis surprizing, that a portion of matter shou'd be able to impart a conspicuous colour to above 256,806 times its bulk of water, and a manifest tincture to above 385,200, and a faint, but yet discernible and distinguishable colour, to above 530,620 times its bulk of water.

We also took a grain of refin'd gold, and having dissolv'd it, without heat, in a sufficient quantity of good *Aqua regia*, we put to it about two spoonfulls of water; and then, by a thread, we hung in the mixture a small piece of a clean metalline body, and kept it suspended in the liquor for many hours. By this means we obtain'd a precipitate of a fine deep colour, so large and light, that it was a long time before it would all settle to the bottom. Then, looking upon the remaining part of the suspended metalline body, we found it so very little less than when the whole was first put in, that the diminution of it was not judg'd to amount to near a grain. By which experiment it appear'd, that one grain of gold, not swimming in parts separately invisible, as in solutions, but reduc'd to a manifest powder, seem'd to make a considerable quantity of precipitate, at the bottom of the cylindrical vial, its diameter, about an inch, wherein we kept it. And this glass, being a little shaken, the precipitate would rise like mud, and be so thoroughly dispers'd in the form of a powder, through the whole body of the liquor, and a

Another of a grain of gold.

PHYSICS. greater quantity of water added to it, that at first it seem'd opaque, and, after some time, appear'd like a high purple solution. So that one grain of gold (for the colour shew'd there was some of that metal, in every corpuscle of the precipitate) was reduc'd into as many grains of powder, as suffic'd to lodge themselves in all the particles of visible space, contain'd in a mass of two ounces of water.

*Animal effluvia
affect the human
body.*

It is deliver'd by approv'd writers, that several persons, by barely holding dry'd cantharides, for some time, in their hands, have felt much pain at the neck of the bladder, and had some other urinary parts sensibly injured; which effects are certainly due to material effluvia, that to get into the mass of blood, must pass thro' the pores of the skin.

Scaliger relates, that in his country, *Gascony*, there are such virulent spiders, that if a man treads upon them to crush them, their poison will pass thro' the soles of his shoes: and *Piso*, in his history of *Brazil*, having spoken of a venomous fish of that country, and the antidotes he had successfully used against its poison; he proceeds to another, which, he says, has this wonderful property, "by the slightest touch of the hand, or even of the foot of him who bruises it through the shoe, to cause a palsy, and a numbness, like the *European* torpedo, tho' less lasting."

But tho' the torpedo's affecting the striker at a distance, seems owing to the stupefactive, or other venomous exhalations issuing from the animal, irritated by the stroke, and breath'd in together with the air they infect; yet their benumbing, or otherwise affecting the arm that struck it, rather than any other part, seems to argue, that the poisonous steams get in at the pores of the skin of the limb, and so stupify, or otherwise injure the nervous and muscular parts of it*. But that some effluvia, even of solid bodies, may be subtil enough to pass the pores of the closest substances, appears from those of the load-stone, which are, by magnetical writers, said to penetrate, without resistance, all kinds of bodies. And tho' I have not try'd this in all sorts, yet having found it true in metals, I am apt to think the general rule admits of very few exceptions; especially if that can be fully made out, which is affirm'd, about the perviousness of glass thereto. For glass is generally reputed to be as close a body, as any in nature; and, I have, by trials, purposely made, had occasion to admire the closeness of very thin pieces of it. But in dials and sea-compasses, which are cover'd with plates of glass, it will be pretended, that the needle may be readily moved by a load-stone held over it; because, these plates being commonly fasten'd only with wax, or at best with cement, the magnetical effluvia pass not through the glass, but through that much more pervious matter employ'd to secure the junctures, only, from the entrance of the air. To clear this mat-

*Even the effluvia
of solids may
penetrate solids.*

* The numbness occasion'd by the torpedo, proceeds from nothing more than an exceeding swift stroke, which the creature usually gives, in order to kill or stupify its prey, by means of two particular muscles, whose office

it is; whence the nerves are, by a communication of this motion, affected in a peculiar manner. *M. Reaumur* gives a very full account of this matter in the *French Memoirs*, A. 1714. p. 417.

ter,

ter, I caus'd some needles to be hermetically seal'd up in glass pipes, which being laid upon the surface of water, whereon they would lightly float, the included needles did not only readily answer to the load-stone externally applied, tho' a weak one, but comply'd with it so well, that I cou'd easily lead, without touching it, the whole pipe to what part of the surface of the water I pleas'd. I also found, that by applying a better load-stone to the upper part of the seal'd pipe, with a needle in it, I cou'd make the needle leap up from the lower part, as near to the load-stone as the interposed glass wou'd give it leave. But I thought it more considerable to manifest, that the magnetical effluvia, even of such a dull body as the globe of the earth, wou'd also penetrate glass. And this I attempted after the following manner. I took a cylindrical piece of iron, about the bigness of ones little finger, and between half a foot and a foot long; having formerly found that the quantity of unexcited iron forwards its operation upon excited needles; and having hermetically seal'd it up in a glass pipe, but very little longer than it, I suppos'd, that if I held it in a perpendicular posture, the magnetical effluvia of the earth, penetrating the glass, wou'd make the lower extreme of the iron answerable to the north pole; and, therefore, having applied this to that point of the needle, in a dial or sea-compass which look'd towards the north, I presum'd, it wou'd drive it away; which accordingly it did. And having, for farther trial, inverted the included iron, and held it in a perpendicular posture, just under the same point, that extreme of the iron rod, which before had driven away this point, being by inversion become a south pole, attracted it; from which sudden change of poles, merely upon the change of situation, it also appeared, that the iron owed its virtue only to the magnetism of the earth; not that of another load-stone, which wou'd not have been thus easily alterable.

Another proof of the great subtilty of effluvia, arises from the small decrease of weight or bulk that a body may sustain by parting with great numbers of them. That bodies infus'd in liquors impregnate them with new qualities, do it by imparting to them somewhat of their own substance, will, I presume, be readily granted by those, who conceive not how one body shou'd communicate to another a solitary naked quality, unaccompanied by any thing corporeal to support and convey it. Glass of antimony, and *Crocus metallorum*, being either of them infus'd in a great proportion of wine, will make it vomitive; and if that liquor be pour'd off, and new put on, every fresh portion of it will be impregnated with the same virtue; and this, tho' the liquor be chang'd abundance of times: yet the antimonial glass, or *Crocus*, are said to continue the same, as well in weight as virtue. But I doubt whether the experiment have been exactly made; for the most ingenious physicians, whom I have question'd about it, acknowledg'd the tast, and sometimes the colour of the wine to be alter'd by the infus'd mineral. However, since after repeated infusions, the mineral substance is not very sensibly diminish'd in bulk or virtue, 'tis a proper instance: for, that there is a powerful emetic quality im-

*Large effluvia
may but little al-
ter the weight, or
bulk of bodies.*

PHYSICS.

parted to the liquor, is manifest by experience; and that the mineral does not impart this virtue by irradiation, as *Helmont* speaks, but by substantial efflux, seems, to me, very probable; not only because 'tis hard to conceive how it can be done otherwise, but because, as we observ'd, the wine often changes colour, by being kept a competent time upon the mineral, as if it drew thence a tincture: and, even when it is not discolour'd, I think it unsafe to conclude, that the menstruum has not wrought upon it; for I have kept good spirit of vinegar, a considerable time, upon finely powdered glass of antimony, made *per se*, without finding this spirit to be at all ting'd; tho' 'tis known, that antimonial glass is soluble in spirit of vinegar; as mine afterwards appear'd to be, by a longer digestion in the same liquor. But there may be a great number of minute particles dissolv'd in the menstruum, before they become numerous enough to change the colour of it. Thus, tho' too great a quantity of the prepared antimony be put into the liquor, yet it will not be thereby made too strongly emetic. For, the wine, being a menstruum, will, like other menstrea, be impregnated but to a certain measure, without dissolving the overplus of the matter put into it. And steel, which is a harder and heavier body than glass of antimony, is itself in part, readily soluble, in rhenish, or other white wine, and sometimes even in water.

'Tis mention'd by *Helmont*, and has been try'd by more than one of my acquaintance, that mercury imparts to water or wine, wherein it has been long infus'd or boil'd, the faculty of destroying worms; without suffering any diminution of its substance.

Having, in a pair of exact scales, suspended a piece of ambergrease, bigger than a walnut, and weighing above an hundred grains, I cou'd not, in three days and a half, that I had opportunity to make the trial, discover any decrease of weight; tho' so rich a perfume lying in the open air, was likely, in that time, to have parted with many odoriferous steams. And, a while after, suspending a lump of *Asa fetida*, for five days and a half, I found it not to have sustain'd any discernible loss; tho', notwithstanding the unfavourable cold season, it had about it an atmosphere, replenish'd with fetid exhalations: and when, 12 or 14 hours after, perhaps upon some change of weather, I came to look upon it, tho' I found the equilibrium somewhat alter'd, yet the whole lump had not lost half a quarter of a grain; which induced me to think, there may, perhaps, be steams discernible by our nostrils, that are far more subtile than the odorous exhalations of spices. For having, in very good scales, suspended, in the month of *March*, an ounce of nutmegs, they lost, in about six days, five grains and a half; and an ounce of cloves, in the same time, lost seven grains and five eighths.

It will doubtless render it more probable, that a small quantity of matter, being scatter'd into invisible effluvia, may be exceedingly rarified and expanded, if I can shew that it may, for a considerable time, emit multitudes of visible parts, and that in so close an order among themselves,

as to seem, in their aggregate, but one intire liquor, endow'd with a streaming motion, and a distinct superficies, wherein no interruption is to be seen, even by an eye plac'd near it. I was induc'd to devise such an experiment, by considering, that all the total dissolutions, hitherto made of pigments, have been in liquors naturally cold, and consisting probably of much less subtile, and certainly of much less agitated parts, than that fluid aggregate of shining matter, we call flame; whence I argued, that if I cou'd once totally dissolve a body compos'd of parts, so minute as those of a metal, into actual flame, and husband this flame so, that it shou'd not immediately waste, I shou'd thereby dissolve the metal in a far more subtile menstruum than common water, *Aqua fortis*, *Aqua regia*, or any other known menstruum I have yet employ'd: and consequently, the attenuation of the metal, in this fiery menstruum, wou'd much surpass, not only what happens in ordinary metalline solutions, but possibly also, what I have noted about the strange diffusion of copper dissolv'd in spirit of sal-armoniac and water. In prosecution of this design, I so prepared one single grain of that metal, as to dissolve it in about a spoonful of an appropriated menstruum; and having caus'd a small glass lamp to be purposely blown to contain this liquor, and fitted it with a socket and wieck, so that it burnt with a large flame, and very hot, tho' without consuming the wieck; seeming all the while of a greenish blue, as if it were but a finer and shining solution of copper; yet this one grain of prepared metal ting'd the flame that was incessantly produced, during no less than half an hour and six minutes. Now, if we consider, that in this flame there was an uninterrupted succession of multitudes of colour'd particles, newly extricated, and flying off in every of those many parts, wherein a minute of time may either actually or mentally be divided; if we consider flame as a light, and very agitated body, passing with a stream upwards, through the air; and, lastly, if we only regard the quantity of liquor that wou'd run through a pipe of a much less diameter than that flame, within the compass of the said time; what a quantity of the streaming fluid, we call flame, if it cou'd have been preserv'd and collected into one body, may we suppose would appear to have issued from one grain of copper, in the space of 36 minutes? And what a multitude of metalline corpuscles may we suppose to have been supply'd to tinge that flame, during so long a time? Since a cylindrical stream of water, falling but through a very short pipe of glass constantly supply'd with liquor, pass'd at such a rate, that tho' the aqueous cylinder seem'd more slender, by two thirds, than the flame; yet we estimated, by the help of a minute-watch, and a good pair of scales, that the water efflux'd in 36 minutes, wou'd amount to above 72 pounds.

The last sort of instances, I shall produce, to shew the strange subtilty of effluvia, is, of such as discover the great quantity of space that may, by a small quantity of matter, when rarified and dispersed, be either fill'd, as to sense, or, at least, made the sphere of its activity.

Tis

A large quantity of space may be possess'd by a very small one of rarified matter.

'Tis surprizing to observe, with what sagacity spaniels take notice of, and distinguish, by the scent, the places where partridges, quails, &c. have lately been; and I have much wonder'd at the quick nose of an excellent setting-dog, who, by his way of ranging, and other motions, especially of his head, wou'd not only intimate to us the kinds of game whose scent he chanc'd to light on, but discover to us where partridges had haunted, several hours before; and assist us to guess how long they had been gone before we came.

I have heard strange things, in *Ireland*, from those who there make a gain of killing of wolves, about the sagacity of that peculiar race of dogs they employ in hunting them. But not trusting much to those relators; a very sober and discreet gentleman of my acquaintance, who has often occasion to employ blood-hounds, assures me, that if a man have but pass'd over a field, the scent will lie so as to be perceptible to a good dog of that sort for several hours after. And an ingenious hunter informs me, he has observ'd, that the scent of a flying and heated deer will sometimes continue upon the ground from one day to the next.

We may here observe, 1. that the substance left upon the grass or ground, by the transient tread of a partridge, hare, &c. probably communicates to the grass, or ground, but some of those effluvia that transpire out of their feet, which, being small enough to escape the discernment of the eye, may, probably, not amount to one grain in weight, or, perhaps, not to the tenth part of it. 2. That the parts of fluid bodies are perpetually in motion, as also the invisible particles that swim in them, as may appear by the dissolution of salt or sugar in water; and the wandering of aqueous vapours through the air, even when the eye perceives them not: And, 3. That tho' the atmosphere of one small parcel of this exhaling matter, may often be very large, in comparison of the body which throws it out; as may be guess'd by the distance at which some setters or blood-hounds will find the scent of a partridge or deer; yet in places expos'd to the free air or wind, 'tis very likely that these steams are carry'd away from their fountain to maintain the forementioned atmosphere, for eight or more hours; that is, as long as the scent has been observ'd to lie, a continual recruit of successive steams is requisite. And so very small a portion of matter, as the fumes of those steams may be supposed, being sensibly to impregnate an atmosphere incomparably greater than itself, and supply it with almost continual recruits, we cannot but think the steams, it parts with, must be extremely minute.

We may farther consider, that the substances which emit these steams, being such as lately belong'd to animals, and were, for the most part, transpired through the pores of their feet, must, in likelihood, be a far more evaporable and dissippable kind of bodies, than minerals or burnt vegetables, such as gun-powder is made of; so that if the grains of gun-powder emit effluvia, perceptible to the scent of some animals, it may be probably suppos'd, that the small grains of this powder will continue
much

much longer to supply an atmosphere with odorable steams; than the corpuscles left on the ground by transient animals. Now, tho' it be generally allow'd, that very few birds have the sense of smelling, any thing near so quick as setting-dogs, or blood-hounds; yet that the odour of gun-powder, especially when assisted by the steams of the *Caput mortuum* of powder, formerly fir'd in the same gun, may, by fowls, be smelt at a considerable distance, particularly, when the wind blows from thence to them; I have often been persuaded, from my own experience in shooting; and was confirm'd in that opinion by sober and ingenious persons, much exercis'd in the killing of wild fowl, and other creatures.

There is an observation of the experienc'd *Julius Palmarius*, whence we learn, that beasts may leave upon vegetables, that have touch'd their bodies for any time, such corpuscles, as, tho' unheeded by other animals, may, when eaten, produce in them the diseases of the infected animals: for, this author writes, in his useful treatise of contagious distempers, that he observed horses, oxen, sheep, &c. to run mad upon the eating some of the straw on which mad swine had lain. Contagious effluvia.

But the effluvia smelt by animals are, tho' invisible, big enough to be the objects of sense; whence, 'tis not improbable, that among the steams which no sense can immediately perceive, there shou'd be some far more subtiler than these, and consequently capable of furnishing an atmosphere much longer, without quite exhausting the effluviating matter that afforded them. *Forestus* gives us an example of pestilential contagion long preserv'd in a cobweb. *Alexander Benedictus* writes also, that at *Venice* a flock bed did, for many years, harbour a pestiferous malignity, to such a degree, that when, afterwards, it came to be beaten, it presently infected the by-standers with the plague. And *Sennertus* relates, that in the year 1542, in the city of *Breslaw*, where he afterwards practis'd physic, there dy'd of the plague, in less than six months, almost six thousand men; from which time, the pestilential contagion was kept, folded up in a linen cloth, about 14 years; and afterwards, being unfolded in another city, it began a plague there, which infected, also, the neighbouring towns, and other places. *Trincavella* makes mention of a yet more lasting contagion, (which occasion'd the death of ten thousand persons) that lay lurking in several ropes, with which, at *Justinopolis*, those who dy'd of the plague had been let down into their graves.

'Tis, indeed, the opinion of several physicians, that the contagion cannot last above twenty days, if the body, it adheres to, be expos'd to the free air and the wind; yet a contagion may, sometimes, happen to be much more tenacious and obstinate. The learned *Diemerbroeck* assures us, that his own apothecary, having but removed with foot, from one side to the other of a little arbour, some straw that had lain under the bed, wherein, about eight months before, a servant of the apothecaries, who recover'd, had been sick of the plague; the infectious steams presently invaded the lower part of his leg, and there produced a pungent pain, and a blister, which turn'd to a pestilential carbuncle, that cou'd

PHYSICS. cou'd scarce be cur'd in a fortnight; tho', during that time, the patient were neither feverish, nor, as to the rest of his body, indispos'd. This memorable instance, together with some other of the like kind, that our author observ'd, extorted from him this confession. "Hence the doctrine of physicians, as to the contagion lurking in a proper subject, receives a confirmation; tho' 'tis surprizing that this contagion shou'd remain so long in the straw; since it had been expos'd to the wind and the rain, the snow and the cold of a whole winter."

In the last place, I shall observe, that such as are skilful in perfuming of gloves imbue them with but an inconsiderable quantity of odoriferous matter; yet I have long had by me a pair of spanish gloves, which, in different hands, have been preserv'd near thirty years; yet are, at present, so well scented, that they probably will continue fragrant for many years longer. Now, as such gloves cannot have been carried from one place to another, or so much as uncover'd in the free air, without diffusing a fragrant atmosphere; we must conclude those odoriferous steams to be unimaginably subtil, that cou'd, for so long a time, issue out in such swarms from a little perfum'd matter lodg'd in the pores of a glove, and yet leave it richly stock'd with particles of the same nature; tho' I never, since I had them, so much as shut them up in a box.

S E C T. II.

The great efficacy of effluvia.

THOSE who trust too much to the negative informations of their senses, without sufficiently consulting their reason, have commonly but a slight opinion of the power and efficacy of effluvia; imagining that such minute corpuscles, as are not usually able to work upon the tenderest and quickest of the senses, cannot have any considerable operation upon their bodies. But this supposition is as ill grounded as it is prejudicial: for tho', *ceteris paribus*, the greatness of bodies, in most cases, contributes to that of their effect upon others; yet matter being, in its own precise nature, an unactive subject, one part of the mass acts upon another, only upon account of its motion, whose operations are facilitated, and otherwise diversified by the shape, size, situation and texture, both of the agent and of the patient. And therefore, if corpuscles, tho' very minute, be numerous enough, and have a competent degree of motion, they may, especially if fitly shaped, when they meet with a body disposed to admit them, and receive their impressions, perform such things in the patient, as visible and much grosser bodies, but less conveniently shaped and moved, wou'd be utterly unable to effect.

The several ways whereby the effluvia of one body may act upon another.

There are at least six ways, by which the effluvia of a body may remarkably operate upon another; as, 1. By the great number of corpuscles

pufcles emitted. 2. By their penetrating and pervading nature. 3. By **PHYSICS.** their celerity, and other modifications of their motion. 4. By the fitness and indisposition of their bulk and shape, to the pores of the bodies they are to act upon. 5. By the motions of one part upon another, which they excite, or occasion, in the body they work upon, according to its structure. 6. By the fitness and power they have to make themselves be assisted, in their operation, by the more general agents of the universe. And tho' there are several cases, wherein a body, that emits particles, may notably affect another body, by one of these single ways; yet the great effects are usually produc'd by the association of two, three, or more of them: so that when I insist upon one, I must not be understood to exclude the rest.

Now, since, as we have seen, the effluvia of a body may be extremely minute; a small portion of matter may, consequently, emit great multitudes of them: and that the number of agents may, in many cases, supply their want of bulk, especially where they jointly act, or resist, appears from some familiar instances.

The number of agents may supply their want of bulk.

We see, that not only the lesser land-floods that overflow the neighbouring fields, but those terrible inundations, which sometimes drown whole countries, are made by bodies, singly so small and inconsiderable as drops of rain, when they continue to fall in those multitudes, we call showers. So the aggregates of such minute bodies, as grains of sand, being heap'd together in sufficient numbers, make banks whereby the greatest ships are sometimes split, and, in most places, the sea itself is bounded. And tho' a single corn of gun-powder, or two or three together, are not of force to do much mischief; yet two or three barrels of those corns, taking fire together, are able to perform prodigious things. Aqueous vapours are look'd upon as the least active effluvia we know; yet when multitudes of them are, in rainy weather, dispers'd thro' the air, and thereby qualify'd to work on the bodies expos'd to it, their operations are very considerable, not only in the dissolutions of salts, and the putrefactive changes of many bodies, but in the swelling they cause in oak, and other solid wood; as appears by the difficulty we often find in, and before, rainy weather, to shut and open doors, boxes, and other pieces of wood-work, that were, before, fit enough for the cavities where-to they had been adjusted. The strings of viols, and other musical instruments, are sometimes strong enough to sustain considerable weights; yet, if left screw'd to their full tension, they are often broken by the moist weather, with great impetuosity and noise.

To try what a number of aqueous steams might do, I caus'd a long slender rope, which was, in part, sustain'd by a pully, to have a weight of lead so fasten'd to the end of it, as not to touch the ground; and after the weight had leisure allow'd it to stretch the cord, as far as it cou'd, I observ'd, that, in moist weather, the watry particles, that invisibly abounded in the air, so affected and shorten'd the rope, as to make it lift up the weight, which was about an hundred pounds.

PHYSICS.

The invisible steams issuing out of the walls of a newly plaister'd room, wherein there is a charcoal fire, are not sensibly prejudicial to those who make but a short stay therein; but we have many instances of persons, who lying for a night in such rooms, have been found dead in their beds, the next morning; being suffocated by the multitude of noxious vapours emitted, during that time.

'Tis proper to observe, that effluvia are not emitted from bodies, all at once, as shot is from a gun; but issue from it, as the vapours out of a well-heated æolipile, or waters out of a spring-head, in continued streams, wherein fresh parts still succeed; so that tho' as many effluvia of a body, as can be sent out at one time, were numerous enough to act but upon the superficial parts, yet the efflux of the next minute may get in a little farther; and each smallest portion of time admitting of fresh recruits, whilst, perhaps, the steams already enter'd are urg'd on, the particles may, at length, get into a multitude of the pores, and penetrate to the very innermost parts of the body.

Some effluvia
very subtle and
penetrating.

That the subtle and penetrating nature of effluvia, may, in many cases, co-operate with their multitude, in producing notable effects; and that there are effluvia of a very piercing nature, will appear from several examples. For, not only the invisible steams of good *Aqua fortis*, and spirit of nitre usually, in a short time, and, in the cold, so penetrate the corks, wherewith the containing glasses were stopp'd, as to reduce them to a yellow pulp; but also, exhalations of mercury have been, sometimes, found in the form of coagulated, or even of running mercury, in the heads, or very bones of those gilders, or venereal patients, who have been too long, or too rashly, exposed to the fumes of it; tho' they never took quick-silver in its gross substance. Chymists too often find in their laboratories, that the steams of sulphur, antimony, arsenic, &c. are able to make those stagger, or, perhaps, strike them down, who carelessly unlute the vessels wherein they had been distill'd or sublim'd; of which I have known many sad examples.

And, of the penetrancy even of animal steams, we may easily be persuaded, if we consider how soon, in many plagues, the contagious, but invisible exhalations are able to reach the heart, or infect other internal parts; for tho', in many of these cases, the blood helps to convey the infection, yet still the morbid particles must get into the body, before they can infect the mass of blood. And in those stupefactions, caus'd, at a distance, by the torpedo, the parts principally affected, seem to be the nervous ones of the hand and arm, which are of the most retired, and best fenced parts of those members. And I make a spirit of sal-armoniac, whose invisible steams, unexcited by heat, are of so piercing a nature, as strongly to affect the eyes, and nostrils, and throats, and sometimes the stomachs too, of those they invade; and when a great cold has so clogg'd the organs of smelling, that neither sweet nor fetid odours wou'd at all affect them; these piercing steams have not only, in a few minutes, made themselves way, but so open'd the passages, that soon after, the patient has

has been able to smell other things also. And, by the same penetrating spirit, a person of quality was restored to the faculty of smelling, which he had lost for several years. Nay, the steams of water itself, assisted by warmth, are able to dissolve the texture even of hard and solid bodies, that are not suspected to be saline; as appears by the philosophical calcination, wherein solid pieces of harts-horn are brought to be easily crumbled into powder, by being hung over water, whilst its steam rises in distillation, and without the help of furnaces. The exhalations, that usually swim every night in the air, and almost every night fall to the ground in form of dews, are, in many places of the torrid zone, of so penetrating a nature, that, as eye-witnesses have inform'd me, they wou'd, in a very short time, make knives rust in their sheaths, swords in their scabbards, and watches in their cases, if not constantly carry'd in the pocket. And I have known, even in *England*, several hard bodies, into which the vapours, floating in the air, have insinuated themselves so far, as to make them friable throughout.

But to shew that the penetrancy and the multitude of effluvia may greatly assist each other, we must not usually look upon effluvia as swarms of corpuscles, that only beat against the outsides of the bodies they invade; but as particles, which, by reason of their great, and frequently recruited numbers, and by their extreme smallness of parts, insinuate themselves, in multitudes, into the minute pores of the bodies they invade, and often penetrate to the innermost of 'em; so that, tho' each single corpuscle and its distinct action be inconsiderable, in respect of the multitude of parts that compose the body to be wrought on; yet a vast number of these little agents, working together upon a correspondent number of the small parts of the body, they may well have powerful effects upon it. Thus the rope, before-mention'd, wou'd not, probably, have been enabled to raise so great a weight, tho' a vehement wind had blown against it, to make it lose its perpendicular straitness; but a vast multitude of watry particles, getting by degrees into its pores, might, like an innumerable company of little wedges, so widen them, as to make the hempen threads swell so forcibly, that the depending weight cou'd not hinder the shortening of the rope. I have, more than once, known solid, and even heavy mineral bodies burst in pieces by the moisture of the air; tho' we kept them, within doors, carefully shelter'd from the rain.

That the celerity of the motion of numberless very minute bodies will have very great effects, may be argued from the wonderful phenomena of fired gun-powder, *Aurum fulminans*, flames that invisibly touch the bodies they work on, whirl-winds, and those streams of invisible exhalations, and other aerial particles we call winds. That the corpuscles whereof odours consist, swim about in the air, as in a fluid vehicle, may be easily prov'd. But the motion of the effluvia of some sufficiently odorous bodies, has too little celerity to make a sensible impression on the organs of smelling, unless the steams be assisted to beat more forcibly upon the nostrils by the air, which hurries them along with it, when it streams into their ca-

Especially, when they all in swarms,

And with great velocity.

PHYSICS. vities in the act of inspiration. Thus we see, when the nostrils of setting-dogs are turn'd to the wind, the current of the air drives the scent of the game, more forcibly, upon the organ.

That a briskness of motion is requisite, and greatly conducive to electrical attractions, appears from the necessity we usually find by rubbing amber, jet, &c. to make them emit those steams, by which, 'tis highly probable, their action is perform'd; and this attrition, I conceive, makes a reciprocal motion amongst the more stable parts, and thereby, as 'twere, discharges and shoots out the attracting corpuscles. That these are actually emitted, appears from an observation I long since made; which was, that if when we took a vigorously excited electric, we did, at a certain juncture of time, place it at a just distance from a suspended hair, or other light body; the hair, &c. wou'd not be attracted to the electric, but be driven away from it, as it seem'd, by the brisk steams that issued out of the electric body.

There is a certain substance, which, being made by distillation in the cold, emits only a very mild and inoffensive smell; but when the vessel, that contains it is heated, tho' no separation of constituent principles appears to be thereby made, the effluvia will be so alter'd, that one, who, to satisfy his curiosity, wou'd needs be smelling to it, when 'twas heated, declared, he thought the steams wou'd have kill'd him; and that the effluvia of spirit of sal-armoniac were nothing near so piercing as these.

Other modifications of motion may give vigour to effluvia.

And among solid bodies, there are some, which, tho' abounding much in a substance wherein rank smells principally reside, yet are scarce, at all, sensibly odorous; but, upon rubbing of them a little, one against the other, so dart out their emissions, as in a minute or two, to make a very offensive smell.

And, as the celerity of motion may thus give vigour to the exhalations of bodies; so there may be other modifications of motion that contribute to the same thing. For not only greater bodies operate differently, according to particular modifications; but even in small particles themselves, it cannot be all one, as to their effects, whether they move with or without rotation, whether in such a particular line, whether with or without undulation, trembling, or such a kind of consecution; and, in short, whether the motion have, or have not, this or that particular modification; which, how much it may diversify the effects of the bodies moved, appears by the motion, that the aerial particles are put into, by musical instruments. For, tho' the effects of harmony, discord, and peculiar sounds, be sometimes very great, not only in human bodies, but in such as are inorganical; the whole efficacy of music and of sounds, that are not extraordinary loud and different, seems to depend upon the different manners of motion whereinto that air is put, which makes the immediate impression on our organs of hearing.

Odd effects of lightning,

As for celerity, and other modes that diversify the motion of effluvia, I shall only, in this place, take notice of those effects of lightning, which seem

seem referable to the celerity, manner of a pulse, to the distinct sizes and shapes of the corpuscles that compose the destructive matter, and to the peculiar relation between the particles of that matter, and the structure of the bodies they invade. Many strange things reported, as the effects of what the *Latins* call *fulmen*, are merely fabulous; but others are not so: some of which I have been an eye-witness of, within less than a quarter of an-hour after the thing has happen'd. And tho' it be very difficult to explain, particularly, many of these true phenomena; yet it seems warrantable enough to argue from them, that there may be agents so qualified, and so swiftly mov'd, that, notwithstanding they are so exceedingly minute, as is necessary to make up a flame which is a fluid body, they must, in an imperceptible point of time, pervade solid bodies; and traversing some of them, without violating their texture, burn, break, melt, and produce other very great changes, in bodies, that are fitted to be wrought on by them. I was once shewn, as a great curiosity, a fine pair of drinking-glasses, somewhat slender, but very tall, which seem'd design'd to resemble one another: but, before I saw them, the resemblance was much lessen'd by the lightning which fell between them, in so strange a manner, without breaking either, that I cou'd perceive it had a little alter'd the figure of one of them, near the lower part of the cavity; but the other was so bent, near the same place, as to make it stand quite awry, in a surprizing posture. It also appears strange to me, that nature shou'd, in the free air, make of perhaps invisible exhalations, such an aggregate of corpuscles, as, without breaking the frail body of the glasses, had a power, in its passage thro' them, that is, in the twinkling of an eye, to melt them; which, even in our reverberatory furnaces, wou'd require a considerable time to do.

Upon hearing a clap of thunder, so near at hand, that I judg'd some of the neighbouring places to be struck; I sent presently to make inquiry, and immediately repair'd to the house where the mischief was done, by something, which, those, who pretended to have seen it coming thither, affirm'd to be like a flame, moved very obliquely. But observing narrowly what had happen'd in an upper room, where it first fell, I saw that it had, in more than one place, melted the lead in its passage, without breaking the glass casements, or burning the bed, hangings, or any other combustible goods, tho', near the window, it had thrown down a large part of a wall, through which it seem'd to have made its passage in or out. And having curiously pry'd into the effects of the *fulmen*, in other places of the house beneath, in whose lowest parts it seem'd to have ended its course; I cou'd not but conclude, that, if it were the same *fulmen*, it must, more than once, have gone in and out of the house; and that the line of its motion was not reducible to any curve or mix'd line I had met with; but that it moved to and fro, in an irregular manner, not unlike the wrigling of fire-squibs. I shall only add, 'tis a known tradition, which my own observations heedfully made seem, now and then, to confirm, that vehement thunder, if beer be not very strong, will usually turn it.

And thunder.

PHYSICS. it four in a day or two's time. Now, if this degeneration be not one of the consequences of the great and peculiar kinds of the concussions of the air that happen in loud thunder, the effect may probably be ascribed to some subtile exhalations diffus'd thro' the air, which, penetrating the pores of the wood, in vessels whose contexture is not very close, imbue the liquor with a kind of acetous ferment. For, considering that the pores of glass are so close, as to be impervious to the steams, or spirituous parts of sulphur, as well as to other odorous exhalations; I thought it worth trying, whether there be any sulphureous steams, or other corpuscles diffus'd thro' the air, in the time of thunder, that wou'd not be too gross to get in at such minute pores as those of glass. And, accordingly, having hermetically seal'd up both beer and ale a-part, I kept them, in the summer-time, till there happen'd a great thunder, for a day or two; after which, the beer that we, in common, drank, which was good before, being generally complain'd of, as turn'd sour by the thunder, I suffer'd my liquors to continue at least a day or two longer, that the souring steams, if any such there were, might have time enough to operate upon them; and then, breaking the glasses, found the liquors good, tho' we had purposely forbore filling the glasses, to facilitate the degeneration. The method of preventing the ill effects of thunder upon barrel'd liquors, if it constantly succeed, deserves also to be here consider'd. This method consists in placing a chafing-dish of live coals, at a convenient distance, under the barrels, when the thunder seems likely to begin.

Effluvia may produce great effects, by exciting a communicative motion in bodies.

The fifth way wherein effluvia, may have considerable effects, is the motion of one part upon another, that they may excite or occasion in the body they work on, according to its structure. But I here propose to shew their efficacy, upon this account, only on organical and living bodies: tho' even inanimate and solid bodies may be of such a structure, as to receive great alterations from the appropriated effluvia of others; as may be instanc'd in the power, that I have known, of some vigorous load-stones, to take away, in a trice, the attractive virtue of an excited needle, or giving a verticity, directly contrary to the former, without so much as touching it.

The load-stone, also, affords an eminent example of the great power of a multitude of invisible effluvia from small bodies, upon such as are inorganic or lifeless; for supposing magnetism to be perform'd by corporeal emissions, we may consider, that these, passing unresisted, through the pores of all solid bodies, and even glass itself; which neither the most subtile odours, nor electrical exhalations are observ'd to do; seem to be almost incredibly minute, and much smaller than any other effluvia, tho' those are invisible; yet such incomparably little magnetical steams, proceeding from vigorous load-stones, will be able to take up considerable quantities of so ponderous a body as iron*. And I have seen a load-

* An experiment made by Mr. Hawksbee, from it, shews, that effluvia, acting with force and vigour, may perform the office of solid bodies. See *Hawksb. Experim.* p. 79—86

stone, not very large, which wou'd keep a weight of iron suspended, that I cou'd hardly raise with one arm; and another little one, with which I cou'd take up above 80 times its own weight. And these effluvia do not only, for a moment, fasten the iron to the stone, but keep it suspended, as long as one pleases.

But the chief effects of effluvia, here to be consider'd, are produced upon animals, which by virtue of their curious and elaborate structure, have their parts so connected, and otherwise contriv'd, that the motions or changes made in one, may have, by the consent of parts, a manifest operation upon others, tho', perhaps, very distant from it.

And, first, 'tis plain, that our organs of smelling are sensibly affected by such minute particles of matter, as the finest odours consist of. Nor do they always affect us precisely, as odours, since many persons, both men and women, are by smells, either sweet or fetid, put into troublesome head-aches. If it were not ordinary, it would seem incredible, that the scent of a pleasing perfume shou'd presently produce in a human body, that immediately before was well and strong, such faintness, swoonings, loss of sensible respiration, intumescence of the abdomen, convulsive motions of the limbs, and many other frightful symptoms, that by the unskilful are often taken for the effects of witchcraft, and wou'd impose upon physicians themselves, if experience did not furnish them with examples of the like phenomena, produc'd by natural means. These symptoms manifest what the consent of parts may do in a human body; since even morbid odours, by immediately affecting the organs of smelling, affect so many other parts of the *Genus nervosum*, as oftentimes to produce convulsions in the extreme parts of the hands and feet.

But the efficacy of effluvia is not confin'd to produce hysterical fits: these invisible particles may be able suddenly to appease them; as I have very frequently try'd, by holding the spirit of sal-armoniac under the nostrils of persons thus affected.

I attribute the operations of these steams rather, in general, to the consent of the parts that make up the *Genus nervosum*, than to any hidden sympathy or antipathy, betwixt them and the womb; because I have known odours produce considerable effects upon men. I am acquainted with a gentleman of a strong constitution, but considerably sanguine, who is put into violent head-aches by the smell of musk. And I, being one day with him, and a great many other persons of note, about a public affair; a man, who had a parcel of musk about him, making application to us, this gentleman was so disorder'd by the smell of it, which to most of us prov'd delightful, that he was reduced to make us an apology, and send the perfum'd man out of the room; notwithstanding which, he for a considerable time after, complain'd to me, of a violent pain in his head, which, I perceiv'd, had unfitted him for the transaction of the affair, whereof he was to be the chief manager. I know another person, who is subject to the head-ach upon so mild a smell as that of damask roses, and, sometimes, even of red roses; so that walking one day with him in
a gar-

Particularly in
those of men.

PHYSICS. a garden, tho' the alleys were very large, so that he might easily keep himself at a distance from the rose-bushes; he abruptly broke off the discourse we were engaged in, complain'd of the offence the perfume gave to his head, and desir'd me to pass into a walk, that had no roses growing near it. I also know a discreet lady, to whom the smell of roses is not unpleasing, but so hurtful, that it presently makes her sick, and wou'd make her swoon, if not seasonably prevented.

And, as odours may thus give men the head-ach, so I have often found the rectified spirit of sal-armoniac, to free both men and women from the fits of that distemper; and sometimes, all of a sudden. And tho' I have not always found so slight a remedy to work the desir'd cure, yet that doing it often, even in men, is sufficient to shew the efficacy of medicinal effluvia.

'Tis a known thing, that women with child have been often made to miscarry, by the smell of an ill extinguish'd candle; tho', perhaps, the smoke, ascending from the snuff, was dissipated into invisible corpuscles, long before it arriv'd at the nostrils of the women: and what violent motions, abortions, are frequently accompanied with, I need not say.

I am acquainted with a physician, who, having for a long time, when young, been compell'd to take lenitive electuary, one of the gentlest and most pleasant laxatives of the shops, conceiv'd such a dislike of it, that still, as himself assures me, if he smell to it, it will work both upwards and downwards with him. Another very ingenious person, of the same faculty, has complain'd to me, that the smell of the grease, used to the wheels of a hackney-coach, tho' the coach do but pass by him, makes him ready to vomit.

Every body knows, that smoke is apt to make mens eyes water, and excite, in the organs of respiration, that vehement commotion, call'd coughing. But we need not have recourse to visible fumes for the production of the like effects; since we have often observ'd them, together, with repeated sneezings, to proceed from the invisible steams of spirit of sal-armoniac, when only small vials, containing that liquor, were put too near, or too hastily to the nostrils. In the foregoing instances, the chief effects seem to be produced by the consent of parts on the *Genus nervosum*, and the action of one of them upon the other; but the following is of a mild and grateful odour, upon the humours themselves.

A famous apothecary, who is a very tall, lusty man, several times told me, that tho' he was once a great lover of roses; yet, having occasion to employ great quantities of them, at a time, their steams have so alter'd him, that, if he now comes among the rose-bushes, the smell greatly discomposes him. And the odour of damask-roses, produces such a flux of humours in his head, that it sets him a coughing, running at the nose, gives him a sore throat, and makes his eyes sore; so that during the season of roses, when quantities of them are brought to his house, he is generally oblig'd to be absent.

And

And as effluvia thus cause one part of a living engine to work upon another, by virtue of its structure, so the action of such invisible agents, may, often, be much promoted by the fabric, and laws of the universe itself; for by operating upon particular bodies, they may dispose, and, now, first qualify them to be wrought upon by light, magnetism, the atmosphere, gravity, or some other of the more universal agents of nature.

S E C T. III.

THE effluvia of bodies being, for the most part, invisible, they have been very little consider'd, by vulgar philosophers; who scarce taking notice of their existence, 'tis no wonder that their distinct natures and differences, shou'd be unknown. *The determinate nature of effluvia.* Aristotle and the schools imagine, indeed, that the two grand parts of our globe do, sometimes, emit two kinds of exhalations or steams: the earth affording those that are hot and dry, which they name fumes, and very often, simply, exhalations; and the water others that are hot and moist, which they, usually, call vapours, to distinguish them from fumes; tho', otherwise, these appellations are frequently confounded.

But, besides such slight and obvious differences, the steams of bodies may be almost as various as the bodies themselves; and, therefore, we ought not to look upon them, barely, under the general and confused notion of smoke or vapours; for they may probably have their distinct and determinate natures, suitable to that of the substance from whence they proceed. *That effluvia may retain the nature of the substances which yield them.*

Now, considering that fluid bodies may be of very unequal density and gravity, as is evident in quick-silver, water, and spirit of wine; and yet agree in the conditions requisite to fluidity; I presum'd, by that I cou'd make visible in one, what happens, analogically, in the other, might be ocularly illustrated. I, therefore, took some ounces of roch-alum, and as much of fine salt-peter: these being dissolv'd together, in fair water, the filter'd solution was set to evaporate, in an open-mouth'd glass, and afterwards left to shoot, in a cool place, when there fallen'd to the sides of the glass, several small crystals, some eight-sided, which is the figure proper to roch-alum, and others of the prismatical shape of pure salt-peter; besides other saline concretions, of neither of these two shapes, distinctly; which argued them to be concoagulations of both the salts. And this we did, by using such a degree of celerity, in evaporating the liquor, as was proper for such an effect. For, by another degree, which is to be employ'd to recover the salts more distinctly and manifestly, the matter may be so ordered, that the aluminous salt shall, for the most part, be first

PHYSICS. coagulated by itself; and then, from the remaining liquor, curiously shap'd crystals of nitre be plentifully obtain'd.

Trials, like this, we also made with other salts, and, particularly, with sea-salt, with alum, and with vitriol. But the present experiment will, alone, assist the imagination to conceive, how the particles of bodies may swim about in a fluid; and, tho' small enough to be invisible, many of them retain their distinct, and determinate natures, and their aptness to cohere, upon occasion; as others may, by their various occurrences and coalitions, unite into less corpuscles, or greater bodies, different from the more simple particles that compose them; and yet not prove of indeterminate, tho' compounded figures.

*And proved by
examples of their
re-union.*

And now we may proceed to particular instances of the determinate nature of effluvia. In the first place then, that the effluvia of many bodies, often, retain a determinate nature, in an invisible smallness, and, oftner, in such a size, as renders them little enough to fly or swim in the air, may appear from hence, that these effluvia being, by condensation, or otherwise, re-united, they prove of the same nature with the body that emitted them. Thus, in moist weather, the vapours of water, that wander invisibly through the air, meeting with marble pillars, pavements, &c. by their coldness, and other qualifications, fit to condense and retain them, appear again, in the form of drops of water; and the same vapours return to the visible form of water, when they fall out of the air in dews, or rains.

Quick-silver itself, if made to ascend in distillation, with a convenient degree of fire, will, almost wholly, come over, in the form of running mercury; which strange and penetrating fluid, is, in some cases, so disposed to be stripp'd of its disguises, and appear again in its own form, that many artificers, and, especially, gilders, will tell us, that the fumes of it need not be, as in distillation, included in close vessels, to return to their pristine nature; real mercury having been, several times, found in the heads, and other parts of those, who have dealt much in it. And, 'tis a common practice, both among gilders, and some chymists, when they have occasion to make an amalgam, or force away the mercury from one, by the fire, to keep gold in their mouths, which by the mercurial fumes, that wander through the air, will, now and then, by that time 'tis taken out, be turn'd almost white, as if it had been silver'd over. A mass of purified brimstone being sublim'd, the ascending fumes will condense into what the chymists call *Flores sulphuris*, which is true sulphur, of the same nature with that formerly expos'd to sublimation; and may, readily, by melting, be reduced into such another mass. And, by subliming good camphire, in close vessels, I found it wou'd all, as to sense, be rais'd into the upper vessel, in the form of dry camphire, as it was before. Nay, tho' a body be not by nature, but by art, compounded of such different substances as a metal, and another mineral, and two or three salts; yet if, upon purification of the mixture, from its grosser parts, the remaining and finer parts be minute enough, and fitly shap'd, the whole

whole liquor will ascend; yet, in the receiver, altogether recover its pristine form of a transparent fluid, compos'd of different saline and mineral parts. This is evident in the distillation of what chymists call butter or oil of antimony very well rectified. For that liquor will pass into the receiver, transparent and fluid, tho', besides the particles of the sublimate, it abounds with antimonial corpuscles, carried over and kept invisible by the corroding salts. I found too, by inquiring of one who had an interest in a tin-mine, that tin itself, tho' a metal, whose ore is of a difficult fusion, and which I have, by itself, kept long upon the cupel, without perceiving it to fly away, wou'd yet retain its metalline nature, in the form of fumes, or flowers. And I have myself, more than once, rais'd this metal in the form of white corpuscles, by the help of half its quantity of an addition.

A second way, whereby we may discover the terminate nature of effluvia, is, from the difference, sometimes, observable in their sensible qualities. For, tho' the effluvia that are endow'd with them, proceed the same sort of bodies; yet those afforded by one body, being, in many cases, manifestly different from what fly off from another, argues their retaining distinct natures, according to those of the respective bodies whence they proceed.

By others, of the difference observable in their sensible qualities.

I will not examine, whether in the steams made, visibly, to ascend from the terrestrial globe by the sun, and the agitation of the air, the eye can manifestly distinguish a diversity of colours; but of some productions of art, such different colours may be discover'd in the exhalations, even without the application of any external heat to raise them. Thus, when spirit of nitre, for example, has been well rectified, I have often observ'd, that, even in the cold, the fumes wou'd play in the unfill'd part of the stopp'd vial it was kept in, and appear of a reddish colour; and if the vessel were open'd, the same fumes wou'd plentifully ascend into the air, in the form of a reddish or orange-tawny smoak. Spirit, or oil of salt, also, if it be well rectifi'd, tho' it will scarce, in the cold, visibly ascend in the empty part of a vial, whilst kept well stopp'd; yet if the air be allow'd free access to it, will fly up in the form of a whitish fume. But this is inconsiderable, in comparison of what happens in a volatile tincture of sulphur, made with quick-lime; for, not only upon a slight occasion, the vacant part of the vial will be fill'd with white fumes, tho' the glass is well stopp'd, but, upon opening the vial, these fumes will largely pass out at the neck, and ascend into the air, in the form of an exceeding white smoak. And both this, and the spirit of nitre, by their operations, as well as smell, discover what they are; so that having, in a fitly-shap'd glass, caught a competent quantity of the ascending white fumes, I found them to have conven'd into bodies transparent, and geometrically figur'd; wherein 'twas easy to observe, from their sensible qualities, that there were numerous sulphureous particles mix'd with the saline ones. That the liquors of vegetables, distill'd *in balneo*, or in water, usually, retain nothing of the colour of the bodies that afforded

PHYSICS. them, is obvious, in distillations made without retorts, or a violent fire; but it may be worth while to try, whether the essential oil of wormwood ascend colour'd, like the plant, when 'tis first drawn over with water in the limbec, or rectified *in balneo*. In a first distillation of this plant, in a copper limbec tinn'd on the inside, I once found the oil came over green, and was not, by a rectification, purposely made in a glass vessel, depriv'd of that colour.

And tho' essential oils be but effluvia of the vegetables they are distill'd from, condens'd, in the receiver, into liquors; yet, notwithstanding their subtilty, many of 'em retain the genuine taste of the bodies whence the heat elevates them. And wormwood is a plant, whose effluvia so retain the nature of the body, from whence they proceed, that coming into a room, where a quantity of it was kept, not only the organs of smelling were, powerfully, struck by the corpuscles which swarm'd in the air; but also the mouth was sensibly affected with a bitter taste. And I have found the expirations of amber, kept a while in pure spirit of wine, taste upon the tongue, like amber it self, when chew'd between the teeth. But the expirations I have obtain'd from amber, both with pure spirit of wine, and a more piercing menstruum, manifestly retain'd the peculiar smell wherewith that substance affects the nostrils, when its electrical faculty is excited by rubbing. And, as for odours, 'tis plain, that the essential oils, well drawn, do many of them retain the peculiar and genuine scent of the spices, or herbs, that afford them. And that these odours really consist of, or reside in, certain invisible corpuscles flying off from the visible bodies, said to be of such smells, may sufficiently appear from their sticking to many of the bodies they meet with, and their lasting adhesion to them.

*Which won'd be
more obvious, if
the human senses
were more acute.*

Other examples may be given of the settled difference of effluvia, directly perceivable by human organs of sense; but I scarce doubt, if our organs were extremely tender, that they might, immediately, perceive in the size, shape, motion, and, perhaps, colour too, of some effluvia, which are now invisible, as distinguishable differences, as our naked eyes, in their present constitution, see between the different sorts of birds, by their appearance and manner of flight. In fine white sand, whose grains, to the naked eye, are not, usually, distinguish'd by any sensible quality, I have, often, observed, thro' an excellent microscope, a notable disparity, as to bulk, figure, and sometimes colour. Nay, I have, sometimes, seen a very evident disparity, even in point of shape, between the eggs of cheese-mites. And tho' the touch is reckon'd one of the most dull of the five senses, and reputed far less quick in man, than in several other animals: yet the gross organs hereof, even in men, may, by accident, be so dispos'd, as to be susceptible of impressions from effluvia: and, perhaps, several of the presages of weather, observable in some animals, and the aches and other pains that, in many crazy and wounded men, usually precede great changes of weather, often proceed from invisible effluvia, which, either from the subterranean parts, or from some
bodies

bodies above ground, plentifully impregnate the air. *Diemerbroeck* tells us of himself, that having been infected with the plague, he was, by the application of a seasonable remedy, quickly cured, without the breaking of any tumour; yet it left such a change in some parts of his body, that when he, afterwards, visited such as were infected with that distemper, he felt a pain in the emunctories, which advertis'd him, that the distemper was the plague.

And an ingenious gentlewoman, of a very curious and delicate complexion, has several times assur'd me, that she can, very readily, discover, whether, a person, who visits her in the winter, came from a place where there is any considerable quantity of snow; and this she does, not by feeling any unusual cold, but from some peculiar impression, which, she thinks, she receives by the organs of smelling. I might add, that I knew, also, a very ingenious physician, who, falling into an odd kind of fever, had his sense of hearing thereby render'd so very nice and tender, that he very plainly heard soft whispers, made at a considerable distance, which were not in the least perceiv'd by the healthy by-standers; nor wou'd have been by him, before his sickness: but when the fever had quite left him, he heard but as other men. I likewise, know a gentleman, who, during a distemper in his eyes, had his organs of sight brought to be so tender, that both himself, and his friends, have assur'd me, when he awak'd, in the night, he cou'd, for a while, plainly see, and distinguish colours, and other visible objects; as was, more than once, try'd, by pinning ribbands, or the like bodies, of several colours, to the inside of his curtains, in the dark.

But there are effluvia which affect other creatures, tho' they make no impressions on men. A person of quality, to whom I am near allied, assur'd me, that, to try whether a young blood-hound was well made, he caus'd one of his servants, who had not kill'd, or touch'd, any of his deer, to walk to a country town, four miles off, and then to a market-town three miles distant from that; which done, this nobleman, a competent while after, put the blood-hound upon the scent of the man, and caus'd him to be follow'd by a servant or two; the master himself going after, to know the event; which was, that the dog, without ever seeing the man he was to pursue, follow'd him, by the scent, to the above-mention'd places, notwithstanding the multitude of market-people who went along in the same way, and of travellers, who had occasion to cross it: and when the blood-hound came to the chief market-town, he pass'd thro' the streets, without taking notice of any of the people there, and left not till he had gone to the house, where the man, he sought for, rested himself; and found him in an upper room. An ingenious gentleman assur'd me, he had dogs, of so good a scent, that if a buck pass'd in a wood, on one day, they will, on the next, when they come near where the scent lies, tho' at such a distance of time, presently find it, and run, directly, to that part of the wood where the buck is.

He:

Some effluvia affect not men, but other creatures.

PHYSICS. He also told me, that tho' an old blood-hound will not so easily fix on the scent of a single deer, that presently hides himself in a whole herd; yet, if the deer be chas'd a little, till he is heated, the dog will go nigh to single him out. The same gentleman farther affirm'd, that he cou'd easily distinguish, whether his hounds were in chase of a hare or a fox, by their way of running, and holding their noses higher than ordinary, when they pursue a fox, whose scent is stronger. These relations will not be judg'd incredible by him, who reflects on some of the instances we have produced, of the strange subtilty of effluvia. And to try whether I cou'd, in some measure, by art, imitate nature, I prepar'd a body, of a vegetable substance; which, tho' it were, actually, cold, and seem'd dry, both to the eye and touch, for a while emitted such determinate and piercing, tho' invisible exhalations, that, having applied to it a clear metalline plate, for about a minute, I found, tho' there had been no immediate contact between them, having, purposely, interpos'd a piece of paper to hinder it; yet, there was imprinted, on the surface of the plate, a conspicuous stain of that peculiar colour, the body, with whose steams I had imbu'd the vegetable substance, was fitted to give to that mix'd metal. And tho', in some circumstances, instances about blood-hounds have a considerable advantage of this experiment, yet they lose it again in others; for here the emitting body was firm and cold; but the effect produced by the effluvia that guided the dog, was upon the organ of a warm living creature, and such an one, whose organs of smelling are of an extraordinary tender constitution, above those of other animals; and probably the impression was but transient; whereas, in our case, the invisible steams of the vegetable substance, wrought upon a body of so strong and inorganical a texture, as a metal, fenc'd by being wrapp'd up in paper; and yet these steams invaded it in such numbers, and so considerably, as to make their operation on it, permanently, manifest to the eye; for, coming to look upon the plate three days after, I found the colour yet conspicuous, and not likely to vanish on a sudden.

Hitherto I have argu'd, from the constant and settled difference of the sensible qualities of effluvia, that they do not, always, lose their distinct natures, when they seem to have lost themselves, by vanishing into air. But it will be alledg'd, that, in many cases, the effluvia of bodies may, in their passage thro' the air, be sensibly alter'd, or affect the organs of sense, otherwise than each kind of them, apart, wou'd do. And, indeed, it seems consistent with experience, that some such cases shou'd be admitted. However, in those I have insisted upon, and many more, such alterations need not hinder, but that effluvia, at their first parting from the bodies whence they proceed, shou'd retain as much of the nature of those bodies, as we have ascrib'd to them; since the subsequent change may, very probably, be deduced from the combinations and coalitions of several steams associating themselves in the air, and acting upon the organs of sense, either conjointly, or, at least so near it,

it, that the sense cannot perceive their operations distinct. Thus, in a musical instrument, if two strings, tun'd to an eighth, be touch'd together, they strike the ear with a sound that will be judg'd to be but one; tho' each of the trembling strings makes a distinct noise, and the one vibrates as fast again as the other. And if, into oil of tartar, *per deliquium*, you drop a due proportion of spirit of nitre, and exhale the superfluous moisture, the acid and alkaline corpuscles, that were so small, as to swim invisibly in those liquors, will convene into nitrous concretions, whose taste will be compounded of, but greatly differ from, both the tastes of the acid and tartareous particles; which particles may yet, for the most part, by a skilful distillation, be divorc'd again. And so, if, to a strong solution of pot-ashes, or salt of tartar, you put as much sal-armoniac, as there is of either of those fixed salts contained in the liquor, you may, besides a subtiler urinous spirit that will easily come over in the distillation, obtain a dry *Caput mortuum*, that is almost, totally, a compound salt, different from either of the ingredients, especially the alkaline, as well in taste, as in some other qualities.

I shall now add a few instances of the coalition and resulting change of steams in the air. 'Tis easily observable, in a nosegay, where the different flowers happen to be conveniently mix'd, that in the smell afforded by it, at a due distance, the odour of the particular flowers are not perceiv'd, but the organ is affected by their joint action, which makes on it a confus'd, but delightful impression. And so, when in a ball of pomander, or a perfum'd skin, musk, civet, &c. are skilfully mix'd; the coalition of the distinct effluvia of the ingredients, that associate themselves in their passage thro' the air, produce, on the organ, one grateful perfume, resulting from all those odours. But if you take spirit of fermented urine, and spirit of wine, both of them weak, and mix them together, they will incorporate, like wine and water, without affording any dry concretions: if you expose them, whilst in a convenient vessel, but to the mild heat of a bath, or lamp; the ascending particles will associate themselves, and adhere to the upper part of the glass, in the form of a white tender sublimate, consisting both of urinous and vinous spirits, associated into a mixture, which differs from either of the liquors, not only in consistence, taste, and smell, but in some considerable operations. And if spirit of salt, and spirit of nitre be, by distillation, elevated in the form of fumes, so as to convene into one liquor, in the receiver; this liquor will readily dissolve crude gold: tho' neither the spirit of nitre alone, nor that of salt, would do so.

And, to give an ocular proof of the possibility of the distinctness, and subsequent commixture of steams in the air, I shall relate an experiment devis'd for that purpose. I took two small vials, the one fill'd with weak spirit of salt, the other with spirit of fermented urine, or of sal-armoniac, very well rectif'd; these vials being unstopp'd, and placed at some distance from one another, each liquor afforded its own smell, by the invisible steams it emitted into the air. But when these vials were brought

Examples of coalitions, and resulting changes of steams.

PHYSICS.

brought very near to each other, tho' not so as to touch, their respective effluvia, meeting in the air, would act upon one another, and, by their mutual occurſions, become manifeſtly viſible, and appear moving in the air, like a little portion of ſmoak, or miſt; which would quickly ceaſe, if either of the vials were remov'd half a foot, or a foot, from the other. And, what adds to the oddneſs of the phenomenon, I, ſometimes, ſuſpended a drop of the ſpirit of ſalt, at the bottom of a little ſtick of glaſs; and held this drop, in the orifice of a vial, containing ſpirit of ſal-armoniac, and furniſh'd with a ſomewhat long neck; whereby the aſcending urinous particles, tho' inviſible before, plentifully invading the acid ones of the drop, produced a notable ſmoak; which, if the drop were held a little above the neck of the glaſs, would, moſt commonly, fly upwards, to the height of a foot, or half a yard; but, if held ſomewhat deep in the hollow of the neck, a large part of the produced ſmoak would often fall into the cavity of the vial, which was left in great part empty, ſometimes in the form of drops, but uſually in that of a ſlender, winding ſtream, of a white colour, that ſeem'd to flow down, juſt like a liquor, from the depending drop, till it had reach'd the ſpirit of ſal-armoniac; upon whoſe ſurface it would ſpread it ſelf, like a miſt.

It might here deſerve to be conſider'd, whether theſe coalitions, of different ſorts of ſteams in the air, and the changes of their particular precedent quantities, reſulting thence, may not aſſiſt us to diſcover the cauſes of ſudden clouds and miſts, and ſome other meteorological phenomena; and alſo of ſeveral changes that happen in the air, with regard to the coming in, and ceaſing, either of epidemical or contagious diſeaſes, and, particularly, the plague. For theſe ſeem to depend upon ſome occult temperature, and alterations of the air; which may be greatly impregnated by the different ſubterranean effluvia, that often aſcend into it with peſtiferous, or other morbiſic corpuscles; ſometimes with others of a contrary nature: and ſometimes too, perhaps, neither the one ſort of ſteams, which may be ſuppos'd to have imbu'd the air, is, in it ſelf deſtructive; nor the other ſalutary, but become ſo upon their caſual coalition in the air. The judicious *Diemerbroeck* tells us, he very often obſerved, during the great plague at *Nimmeguen*, that the diſtemper conſtantly happen'd in ſuch houſes, wherein linen was waſh'd with *Dutch* ſoap; and that always, the ſame day, or the day after, two or three perſons would fall ſick together, in the ſame houſe; they themſelves acknowledging, that the ill ſcent of the ſoapy water, wrought the firſt great change in them. He adds, alſo, that he had the unwelcome experience of this, in his own houſe; where, immediately upon waſhing, moſt of the family were taken ill: but three women fell ſick of the plague on the night following, and dy'd ſoon after. Now tho', perhaps, ſome other cauſe of this odd phenomenon may be deviſ'd, yet, that which I aſſign, ſeems, at leaſt, a probable one; ſince, as 'tis manifeſt, by daily experience, the ſmell, occaſion'd by the waſhing of foul linen, with the ſoap, commonly us'd in the *Netherlands*, pro-

Whence, probably,
meteors, conta-
gious diſeaſes, and
their removal.

produces not the plague; so, by our author's observation, it appears, either that there were not yet any pestilential effluvia in the air of those places, which, on occasion of the washing, became infected; or, at least, that, by the addition of the fetid effluvia of the soapy water, those morbid particles, that were dispers'd thro' the air before, had not the power to introduce a malignant constitution into it, and to act as truly pestilential, till they were enabled to do it, by being associated with the ill-scented effluvia of the soap.

Whether, also, salutary, and alexipharmic corpuscles, may not be produced in the air, by coalition, might be very well worth our inquiry; especially, if we had a good historical account of the yearly ceasing of the plague at *Grand Cairo*. For, as *Prosper Alpinus*, who practised physic there, and some of my acquaintance, who have been upon the spot, inform me, almost in the midst of summer, as soon as the river begins to rise, the plague has its malignity suddenly check'd, even in those who are already infected; and soon after ceases: whence, if other circumstances contradict not, we might guess, that this strange phenomenon may be chiefly occasion'd by some nitrous, or other corpuscles, that accompany the overflowing of the *Nile*; and, by associating themselves with the noxious effluvia, disable them from producing their pernicious effects. Mr. *Sandys* takes notice, that about the time of the overflowing of the *Nile*, whose abounding with nitre has been observ'd, even by the ancients that, there is a certain moistening vapour diffus'd thro' the air. "To prove," says he, "that the overflowing of the *Nile* proceeds from a natural cause, this experiment will suffice. Take of the earth of *Egypt*, adjoining to the river, and preserve it carefully, that it neither come to be wet, nor wasted; weigh it daily, and you shall find it neither more nor less heavy, till the 17th of *June*, at which day it begins to grow more ponderous, and increases with the augmentation of the river; whereby they have an infallible knowledge of the state of the deluge, proceeding, without doubt, from the humidity of the air, which having a recourse thro' all passable places, and mixing therewith, increaseth the same as it increaseth in moisture". That these sanative steams perform their effects, merely because they are moist, I presume, will scarce be pretended; but that they may be of such a nature, as, by their coalition with the morbid corpuscles, to increase their bulk, and alter their figure, or precipitate them out of the air, or clog their agility, or pervert their motions; in a word, destroy all, or some of those mechanical properties which render'd them pestilential, and this so that there may result, from the association of two sorts of particles, whereof one was of a highly noxious nature, a harmless mixture, might here be made probable from several considerations. Let me add, that having purposely made a visible and lasting stain, on a solid body, barely by cold effluvia, I did, by the invisible and cold steams of another body, make, in two or three minutes, a visible change in the colour of that stain.

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That

PHYSICS.

That meteors may, sometimes, be produced, by the occurrences of subterranean effluvia, some of them of one determinate nature, and some of another, I might shew, by various instances of the plentiful impregnation of the air, at some times, and places, with steams of very different natures; and such as are not so likely to be attracted by the heat of the sun, as to be sent up from the subterranean regions, and sometimes from minerals themselves. And tho' the effluvia, arising from the bowels of the earth, are sometimes ill-scented, yet, they are not always so. And sulphureous exhalations from cold and aqueous liquors, may be shewn to retain their determinate nature in the air, and, accordingly, to act upon solid bodies, to whose constitution they chance to prove proportionate.

The experienc'd *Agricola*, having mention'd, out of ancient historians, the raining of white and red liquors, which they erroneously took for milk and blood, subjoins. "This may be the more easily credited, because, in our father's memory, drops fell from the air, in *Sweden*, "which stain'd such clothes as were made of linen, with red crosses, "as if they had been blood". And 'tis the less improbable, that the more agile corpuscles of subterranean salts, sulphurs, and bitumens, may be rais'd into the air, and keep their distinct natures in it, if so fix'd a body, as common earth it self, can be brought to swim in that fluid; yet, the same *Agricola* assures us, that he saw rain fall, so mix'd with clay, that the streets were every where cover'd with it.

And to shew, that, in some cases, the particles even of vegetable bodies, may not so soon perish in the air as they disappear in it, but retain distinct natures, at a greater distance than one would imagin, from the bodies that plentifully emit them, I shall add, that an ingenious gentleman, who went on a considerable employment to the *East-Indies*, acquainted me that, sailing along the coast of *Ceylon*, famous for cinnamon-trees, and well-scented gums, the wind, which then chanced to blow from the island, brought them a manifestly odoriferous air, tho' they kept off, perhaps 20, or 25 miles from the shoar. Nor should this be thought incredible because the diffusion seems so disproportionate to that of other bodies dissolv'd by fluids; as for instance, tho' salt be an active body, and resolvable into abundance of minute particles, yet, one part of salt will scarce be tasted in an hundred parts of water. For, sensibly to affect so gross an organ, as that of our taste, there is usually required in sapid particles, a bigness far exceeding that which is necessary to make bodies fit objects for the sense of smelling. Besides, there is a great difference between the power a body has to impregnate so thin and fine a fluid as the air, whose parts are rare and lax, and that which it has to impregnate liquors, such as water, or wine, whose parts are so crowded, as to make it visible, tangible, and ponderous. And I found, by trial, that one drop of good chymical oil of cinnamon, being duly mix'd, by means of sugar, with wine, retain'd the determinate taste of cinnamon, tho' it was diffus'd into near a quart of it: whence I concluded, that, upon the common supposition, according to which a drop

drop is reckon'd for a grain, one part of oil had given the specific taste of the spice it was drawn from, to near fourteen thousand parts of wine. By comparing this experiment with what I noted, about the proportion of salt requisite to communicate a taste thereof to water, it will easily appear, that there may be a very great difference, in point of diffusiveness, between the little particles that make bodies sapid. I must not omit, that, besides the almost innumerable sapid parts of a spicy drop communicated to the wine, it thence diffused a vast number of odoriferous particles into the air; which both I, and others perceiv'd to be imbued with the distinct scent of cinnamon: and the liquor was able to have render'd it spicy for a very long time.

The third, and last way I shall mention, to shew the determinate nature of effluvia, arises from the consideration of their effects upon other bodies than the organs of our senses. For the effects that certain bodies produce on others by their effluvia, being constant and determinate, and often very different from those which other agents, by their emissions, work upon the same, and other subjects; the distinct nature of the corpuscles emitted, may be thence sufficiently gather'd.

The third way of determining the nature of effluvia, by their effects on bodies different from the organs of sense.

Now, the temporary numbness, or stupefaction, produced in the foot, by the effluvia of the fish, which we formerly took notice of, as mention'd by *Piso*, manifests, that those stupefying exhalations retain a peculiar and venomous nature, during their whole passage thro' the shoe, stocking, and skin, interpos'd betwixt the fish and the nervous part of the foot, benumb'd by it. And tho' there are few other bodies, in the world, minute enough to pass thro' the pores of glass; 'tis apparent, by the experiment of iron, hermetically seal'd up in a glass-pipe, that the magnetical effluvia of the earth may retain their peculiar nature, in a smallness that qualifies them to pass those freely.

That several bodies, of a venomous nature, may exercise some such operations upon others, by their effluvia transmitted through the air, as they usually do in their gross substance, is a truth whereof there are some examples among physicians. *Sennertus* observes, as a known thing, that apothecaries servants have been cast into profound sleeps, when, in distilling opiate and hypnotic liquors, they have receiv'd in, at their nostrils, the vapours exhaling from those bodies. 'Tis recorded by the writers on poisons, that the root and juice of mandrake cast those who take them, into a deep sopor, not unlike a lethargy. And tho' the apples of the same plant, are thought much less malignant, yet *Levinus Lemnius* relates, that having laid some of them in his study, he was, by their steams, more than once, made so sleepy, that he could hardly recover himself; but, the apples being taken away, he regain'd his vigilance and alacrity.

Among all poisons there is scarce any whose phenomena, in my opinion, are more strange, than those that proceed from a mad dog; yet, even this poison, which seems to require corpuscles of so odd and determinate a nature, is recorded, by physicians, to have been convey'd

PHYSICS.

by exhalations. *Aretaus* writes, that a man, who was never bit, but only receives the breath of a mad dog, will grow mad; and, we have accounts of animals that become mad, by having eaten of the parts or excrements of those who were mad. So *Calius Aurelianus*, tells us, that some have been made to run mad, not by being bitten, but wounded only with the claws of a mad dog; and adds, that a man fell into a hydrophobia, without being bitten, but infected by the smell of a mad dog; whereby I understand a swarm of effluvia, which are, most commonly, all, or, at least, some of them, odorous. And, tho' it may seem strange, that the venom of a mad dog should be communicated otherwise than by the bite; 'tis the less improbable because *Matthæus de Gradibus* names a person who prov'd infected many days after having put his hand into the mouth of a mad dog that did not bite him. And *Matthiolus* relates, that he saw two who were made mad without any wound, by the bare flabber of a mad dog. *Sennertus* affirms it of a painter of his acquaintance, who, when he open'd a box, in which he had long kept included realgar, a noxious mineral, sometimes used by painters, and not unknown to chymists; and had unfortunately snuff'd in the steams of it; that he was seiz'd with a giddiness in his head, and fainting fits; his whole face also swelling; tho', by taking of antidotes, he saved his life.

The probability of what I have thus cited, from credible authors, may be strengthened by the following proof of the distinct nature of effluvia. A physician of my acquaintance, causing a large quantity of black hellebore-root to be long pounded in a mortar, most of those who were in the room, and, especially, the person who powder'd it, were thereby purged, and some of them strongly. *Sennertus* affirms, that some will be purg'd by the very odour of colocynth. And in the cases I have alledg'd, exhalations, endow'd with occult qualities, (as cathartic medicines are supposed to be) ascend into the air, without being forced from the bodies they belong'd to, by any external heat.

And, if I were here to alledge the operations of such effluvia as do not pass into the air, but operate only by the contact of the external parts of the body, I cou'd give instances, not only of the purgative, but the emetic qualities of some medicines exerted without being taken in at the mouth, or injected with instruments.

There are, also, other sorts of examples than those hitherto mention'd, that argue a determinate nature in the effluvia of some bodies emitted into the air. Approved writers tell us, that the shadow of a walnut-tree, with the leaves on it, is very hurtful to the head; and some instances they give us, of great mischief it has sometimes done: and tho' this shadow is not likely to produce such a bad effect, yet the effluvia of the neighbouring plant may be noxious enough to the head. For I, being not at all prepossess'd with this opinion, without scruple resorted to the shade of walnut-trees, in a hot country; but was, by experience, forced to think it might give others the headach, since it did to me,
who

who are very little subject to that distemper. Some ingenious travellers into the *West-Indies* affirm, that birds will, there, not only forbear to eat of the fruit of venomous plants and trees, but will not so much as light on some of them; which nature, probably, instructs them, by some noxious smell, or other particular effluvia, to avoid. And some of our navigators give it for a rule, to those who happen to land in unknown islands, that they may venture to eat such plants or fruits, which they can perceive the birds to have been pecking at before. *Nicolaus Florentinus* tells us of a certain *Lombard*, who having, in a house at *Florence*, burned a great black spider, at the flame of a candle, so unwarily, that he drew in the steams of it at his nostrils, presently began to be much disorder'd, and fell into a fainting fit, and, for the whole night, had his heart much disaffected; his pulse being so weak, as hardly to be perceiv'd; tho' he was, afterwards, cured by a mixture of *Venice-treacle Diamoschus*, and the powder of zedoary. In *Ireland*, I gather'd a certain plant peculiar to some parts of that country, which the natives call *Maccubuy*, whose operations are odd and violent. This plant, a physician, to make an extract, caus'd his man to beat in a mortar; but he was soon obliged to desist; and the doctor himself, tho' at a distance off, was so affected by the corpuscles that thence issu'd out into the air, that his head, and particularly his face, swell'd to an enormous size, and continu'd tumid for a long time after.

'Twill be needless to produce more instances to shew the determinate nature of effluvia, small enough to wander through the air, if we consider, that many odoriferous bodies, for instance, amber, musk, civet, &c. as they will, by the adhesion of their whole substance, perfume skins, linen, &c. so they, in time, perfume some bodies dispos'd to admit their action, tho' kept at a distance from them; and that, in pestilential fevers, and other contagious distempers, as the plague, small-pox, &c. the same determinate disease is communicable to sound persons, not only by the immediate contact of one who is infected, but without it, by the contagious steams that exhale from his body into the air.

To conclude with an experiment; having found that volatile and sulphureous salts wou'd so work upon some acid ones, sublim'd with mercury, as to produce an odd diversity of colours, but chiefly an inky one; I took an ounce, or more, of my volatile tincture of sulphur, made with quick-lime, sulphur, and sal-armoniac, and stopp'd it up in a vial capable of containing, at least, twice as much; then taking a paper, whereon something had been written with invisible ink; I laid it down six inches from the vial, which, being unstopp'd, began, upon the access of the air, to emit white fumes into it; and by these, what was written upon the paper, notwithstanding its distance from the liquor, quickly became very legible, tho' not quite so suddenly, as if a paper, written upon with the same clear liquor, were held at the like distance, directly over the orifice of the vial. And having caus'd several pieces of clean paper

PHYSICS. paper to be written on with a new pen, dipt in the clear solution of sublimate made in water, 'twas pleasant to see how the letters of these several papers, being plac'd within some convenient distance from the vial, would be made plainly legible, and some of them more, some less blackish, according to their distances from the smoaking liquor, and other circumstances. But 'twas more surprizing to see, that when I held, or laid some of these papers, tho' with the written side upwards, just upon, or over the orifice of the vial, tho' the contained liquor did not reach so high, by some inches, yet the latent letters would become conspicuous in about a quarter of a minute. And, as it may be observed, that, in some circumstances, the smoaking liquors, and the solution of sublimate, will make an odd precipitate, almost of a silverish colour; so, in one or two of our trials, we found a like colour produced by the steams of that liquor, in some of the colourless ink. Nor is it necessary to employ a visibly smoaking liquor to blacken the invisible ink at a distance: for I have, to that purpose, with good success, employ'd two liquors, wherein there was neither sulphur, sal-armoniac, nor sublimate; and causing something to be written, with dissolv'd sublimate, upon a piece of paper, we folded the paper with the written side inwards, and then wrapp'd it up in the midst of six sheets of paper folded, singly, on each other, in the form of an ordinary letter or packet; so that the edges of the inclosing paper being inserted, one within the other, the fumes might not get into this written paper, but by penetratnig through the leaves themselves: then, that side of the packet, on which the superscription is usually written, was laid upon the orifice of the vial, and left there about ten minutes; after which, taking off the folded papers, and opening them, we found, that the steams had pervaded all the leaves, in which the written paper was inclosed: for, tho' these did not appear stained, or alter'd, yet the characters, latent before, appear'd conspicuous.

For farther satisfaction, we took a printed book, which we judg'd the fittest for our purpose, because, the leaves being broad, they might the better preserve a small paper, placed in the midst of them, from the exhalations sideways; and having put the design'd paper into this book, and held it to the orifice of the vial, while no less than twelve leaves interpos'd, yet, those letters that happen'd to be the most rightly plac'd, were made inky in three minutes time; tho' this liquor had been so long kept, and so often unstopp'd, to try experiments, that it had, probably, lost a great part of its most spirituous, and penetrating particles.

THE
P O R O S I T Y
O F
B O D I E S,
C O N S I D E R' D.

S E C T. I.

AS the greatest part of the pores in bodies, is too minute to be visible, so the contemplation of them has been thought inconsiderable. *The porosity of animal bodies.*

But, since most qualities depend upon the structure of the minute and invisible particles of bodies; and since interstices and pores, necessarily concur thereto; the doctrine of porosity must be of great importance in natural philosophy. I will therefore freely communicate what observations I have made relating to this subject, as they occasionally occur'd to me; and, first, as to the porosity of animal bodies. But I shall not here be solicitous to distribute and range my observations; since they all conspire to shew but this one thing; that the parts of animals, especially whilst alive, are furnish'd with numerous pores. *

* Sir *Isaac Newton* observes, that bodies are much more rare and porous, than is usually imagin'd. "Water," says he, "is 19 times lighter, and, by consequence, 19 times rarer than gold; and gold is so rare, as very readily, and without the least opposition, to transmit the magnetic effluvia, and easily to admit quicksilver into its pores, and to let water pass through it. For, a concave sphere of gold, fill'd with water, and folder'd up, has, upon pressing the sphere, with great force, let the water squeeze through it, and stand all over its outside in multitudes of small drops, like dew, without bursting or cracking the body of the gold; as I have been inform'd by an eye-witness. From all which we may conclude, that gold has more pores than solid parts; and, by consequence, that water has above 40 times more pores than parts." *Newton. Optic. p. 242.*

And

PHYSICS.

*Shewn from the
structure of their
stable parts*

*From the man-
ner of their nutri-
tion.*

And this porosity is deducible from the frame or constitution of the stable parts of an animal body; which being a curious engine, admirably contriv'd for the exercise of several functions, it was necessary it should be supplied with variety of dissimilar and organical parts. And because the corpuscles, brought together for such purposes, must be so interwoven, as not exactly to touch one another every where; it will readily follow, that they must leave little intervals or pores between them; and that, considering the multitude of particles employ'd to make up the body of an animal, and the great difference and variety, in point of bulk and figure, of the corpuscles requisite to constitute such different parts; both the number and variety of the pores cannot but be very great. The necessity of pores in animal bodies, may, likewise, be deduced from their manner of nutrition; for, a great waste being continually made of their substance, by the exclusion of visible excrements, and the avolation of invisible steams; this must, necessarily, be repair'd by nutrition, of which the best account is, that the alimential juice, prepared chiefly in the stomach, being impelled to the several parts of the body, and the corpuscles of the juice insinuate themselves at the pores they find adapted to their bigness and shape; whence those which are most agreeable, being assimilated, add to the substance of the part wherein they settle, and so repair what was lost before by that part. This may be illustrated from plants, in which, of the various corpuscles found in the liquors of the earth, and agitated by the heat of the sun and the air, those, that happen to be commensurate to the pores of the root, are, impell'd into it, or imbib'd by it, and thence convey'd to the other parts of the tree, in the form of sap; which, passing thro' new strainers, receives the alterations requisite to their conversion into wood, bark, leaves, blossoms, fruit, &c. But to return to animals; our argument, from their nutrition, will be much confirmed by considering that in children, and other young animals, which have not yet attained their due bulk, the nutrition is so large, as to amount to a continu'd augmentation. For, as it is evident that animals grow in all their parts, and in each part, according to all its dimensions; so we cannot well conceive how this should happen, unless the nutritive liquor be distributed through the whole of the part to be augmented; and to this distribution it is requisite, that the body abound with pores, into which the suitable particles of the juice may be admitted.

*From their sweat
and perspiration.*

Having premised, once for all, that I often use the word, skin, in the popular sense, without distinguishing the *Cuticula*, or scarf-skin, from the *Cutis* it invests, I proceed to another topic, whence the porosity of animals may be argu'd; namely, the great plenty of matter, daily carried off by sweat, and insensible perspiration. For, sweat is allow'd to be discharg'd at the pores of the skin: and since there is no penetration of dimensions, we may conclude, that the matter wasted by sweat, must have small out-lets in the skin: and invisible effluvia may also evaporate at the same pores. That therefore the skins of many animals, tho

tho' they seem close to the eye, may be porous, appears from their sweating. But because all of them have not been observed to sweat, particularly dogs, we shall add some other instances, to make this more universal.

We may sometimes, in the skin of a living man, discern pores, with good microscopes; and easily, on the inside of gloves, which are made of skins dressed, perceive numbers of these little out-lets, orderly ranged: and tho' some of them may be suspected to have been made by the hairs, which grew on the skin, before it was dress'd; yet, that greater numbers of them are perforations quite through the leather, is manifest from the usual practice of chymists, in straining quick-silver through sheep-skins. And tho', when a man's skin is tanned, it be of a great thickness; yet, trying the same experiment with the skin of a man's arm, I found that quick-silver could be squeezed out at the pores of this also. It is unnecessary here to enquire, whether these little holes be not the orifices of small excretory vessels, or glands, which *Steno*, and *Malpighi* discover'd beneath the *Cuticula*, call'd *Glandulae Miliares*; for, according to this opinion also, a multitude of small perforations must be allow'd in the skin; and that is sufficient for my purpose, from whence soever the porosity proceeds. But the next observation will shew, that some membranes of animals may give passage to transpired matter, without being perforated by the excretory vessels of glands. The skins under the shell of hens eggs, are of a texture, very fine and close; yet, both these, and the shells which cover them, are porous; because the egsg, with keeping, manifestly lose in weight: which must be imputed to invisible transpiration; and the rather, because in those, which have been long kept, there is found a cavity at one end, that increases with their age, and is made by the shrinking of the membrane from the shell.

Considering the large quantity of matter, discharged by insensible perspiration in healthful men, the pores must, doubtless, be very numerous; and much more so, than by the drops of sweat, which wet the skin, we usually imagine. For, *Sanctorius* affirms, that what is barely carried off by insensible transpiration, ordinarily amounts to more, that is, diminishes the weight of a man's body, more than all the visible excrements together. He adds, if the aliment, taken in one day, amounts to eight pounds, the insensible transpiration usually amounts to five. And he elsewhere asserts, that in the space of twenty four hours, in the winter-time, an healthy body may exhale above fifty ounces: and some trials, both of my own, and others, confirm *Sanctorius's* observations; * allowance being made for the difference of heat between *Italy* and *England*: only, I fear, an over-sight has been committed by those, who

* Dr. *James Keil* hath given a sett of observations, made by himself, after the *Sanctorian* manner, under the title of *Medicina Statica Britannica*; which confirms the doctrine of perspiration in general, and shews the differences of it

between our climate, and such as are hotter; tho' it embarrasses this doctrine considerably, that the human body seems to take in something from the air, which may increase its weight upon the balance.

PHYSICS.

ascribe all the decrease of weight, not referable to the grosser excrements, to what transpires at the pores of the visible parts of the skin; without taking notice of what is, in expiration, discharged through the wind-pipe, and appears manifest to the eye, in frosty weather. But tho' I look upon the wind-pipe as the great chimney of the body, in comparison of those little ones; yet, the number of these is so very great, that the exhalations which steal out at them, must be very considerable. Besides, those, that are discharg'd at the *Aspera Arteria*, do, probably, for the most part, issue out of the membranes investing the lungs; which membranes may be look'd upon as external parts of the body, with regard to the air. But we may safely allow a very great evacuation, at the pores of a man's skin, who is a sanguineous and hot animal; since we see that eggs, which are actually cold, transpire. Nay, even frogs, which are always cold to the touch, exhale largely; and the decrease in weight of some animals, soon after they are suffocated, is considerable. We may add, the experiment of holding any part of the body, in warm weather, near to a solid or smooth substance, as a piece of polish'd steel or silver; which will presently be sullied with steams, issuing out of the pores.

Farther, the perviousness of the skin outwards, may be argued from the quickness, wherewith some medicines take away discolourations of it by contusions; which is, very probably, performed by attenuating the matter, and disposing it to perspire: tho', perhaps, when it is thus changed, some part of it may be imbibed again, by the capillary vessels. *Helmont* speaks much of the virtue of white briony root, in such cases; and the fact was lately confirmed, from an experiment made by an acquaintance of mine. I knew an eminent person also, cured of a contusion, which made the part look black and frightful, by the bare use of of hyssop, and fresh butter, applied in the form of a poultis. Nor is it only the skin, that covers the visible parts of the body, which we judge to be thus porous, but also the membranes, that invest the internal parts. For the two first-mentioned causes of porosity, are as well applicable to them, as to the external skin; and, in some respects, the transpiration through such pores, seems more advantaged, than that through the pores of the surface; since the parts surrounding the spleen, liver, kidneys, &c. in man, are hot, in comparison of the ambient air; and being also wet, which the air is not, the laxity of the pores of the internal parts is doubly befriended: and we conceive both the skin, and membranes, to be like net-work; which, in their ordinary state, have a kind of continuity; but, upon occasion, can suffer their pores to be every way enlarged, as external agents determine. And this porosity of the internal membranes, will the more easily appear from the perviousness of the bladders of dead animals, even to water; which we have try'd, by putting some salt of tartar in a clean well-dry'd bladder, and leaving the lower part immers'd in common water, whose particles, by degrees, insinuated themselves into the bladder, so as to dissolve the salt into a liquor:

liquor: and this experiment succeeded, but much more slowly, with sugar instead of salt of tartar. And there are some who pretend, that certain syrups, made this slovenly way, which they would have pass for for a secret, are vastly preferable to those made of common water. That even the films, which line the shells of eggs, tho' of a very close texture, are, yet, pervious to liquors, appear'd by keeping an ordinary hen's egg, for two or three days, in distill'd vinegar: for then taking it out, we found it entire, and visibly swell'd. And, what satisfi'd us, that the expansion proceeded from some other cause, than the mere dilatation of the white, or yolk, or both; the egg now proved considerably heavier than before its immersion, notwithstanding the loss of its shell. And, on this occasion, may be added, that the *Chinese* have a way of salting eggs in the shell. In one of the *Dutch* journals sent, by the council of *Batavia*, to their principals in *Holland*, I met with several accounts of salted eggs, brought, by sea, into *Batavia*, and other ports: after which, meeting with a physician, who liv'd in *Batavia*, I learnt from him, that such eggs are frequently met with in those parts; he having several times eaten of them there, and found they retained a briny taste, when dress'd. The merchants, of whom I enquired, could not tell me, what way the *Chinese* employ to salt, and preserve their eggs; but having coated one with clay, and suffer'd it to lie, for a competent time, in brine, I found its taste considerably salt, when broke.

I knew a physician, who, being tormented with a peculiar kind of colic, reliev'd himself by glysters of sack; but usually found, that they would inebriate, and make him giddy: and a surgeon, who practis'd in the *West-Indies*, told me, that having dress'd, with the juice of tobacco, a small ulcer in a woman's leg, the patient, soon after grew sick, and actually vomited. But, on this instance, I lay no stress; because the corpuscles of the tobacco might get in at the small orifices of some corroded vessels, and so be convey'd internally, rather by the help of the circulation of the blood, than on account of the porosity of the parts. But a physician, of the college of *London*, assured me, that he had several times given himself a vomit, by the application of tobacco to his wrists, and some other external parts; and some children have been made drunk by cloaths, wetted in the infusion of tobacco, and applied to their heads for scabbiness in that part: tho', in this case too, the inebriating particles may get in, not at the mere pores, but at the orifices of the capillary vessels, that were made accessible by such little solutions of continuity, as are seldom wanting in such cases. But that children may be purged by outward applications is asserted by physicians; and an experienced person has affirmed to me, that he can almost constantly purge them by a plaister. But it is more considerable, what was related to me by a person of eminence, who, being indisposed to believe such things, had his hand barely moisten'd by another, with a subtle chymical oil, which the former regarded not, till he found him self press'd with a motion, like that which a purge would have given him; and was

PHYSICS.

purged four times without griping, or other pain. But to return to the porosity of membranes; it may serve to prove it, that lute-strings, which being only fibres, are the chief parts of which membranes consist, will, sometimes, in wet weather, swell so forcibly, as, with noise and violence to break; which proceeds from moist vapours entering at their pores.

From the trans-
lation of morbid
matter.

This porosity of the internal parts of animals may be also confirmed by what happens in the translation of the morbid matter in diseased bodies. For, often the matter, which in the sanguiferous vessels produced a fever, being discharged upon some parts of the head, produces a *Delirium*, or *Phrenitis*; in the latter of which, I have wonder'd to see the patient's urine like that of a person without a fever. The same febrile matter is discharged sometimes upon the *Pleura*, throat, or intestines; and causes in the first a pleurisie, in the second a quinsie, and, in the third a flux, generally dysenterical. But because most of these translations of peccant humours are made by the circulating blood, I am content to intimate, that some of them may confirm the porosity here spoken of. And this, in effect, is already proved by the same arguments whereby we have shewn, that both the skin, and the internal membranes, are furnish'd with pores, pervious to particles, whose shapes and size are correspondent to them. For it appears, that when morbid matter, whether in the form of a liquor, or of exhalations, chances to have corpuscles suited to the pores of this or that part, it may, by a concurrence of circumstances, be determin'd to invade it; and so dislodge from its former receptacle, and excite new disorders in the parts it removes to.

And from the in-
gress of effluvia.

Another thing, whence the porosity of animals may be argued, is their receiving effluvia from without. For these cannot get into the internal parts of the body, to perform their operations there, without penetrating the skin, and consequently entering the pores of it. Now that things, outwardly applied, may be convey'd to the internal parts, is notorious, in the instances of cantharides; which produce great disorders in the urinary passages, and sometimes cause bloody urine. The same may be also concluded from various effects, even of milder plaisters: for tho' some operate, perhaps, by closely sticking to the skin, hindering perspiration, and fencing the part from the external cold; yet 'twill scarce be denied, that many of them have notable effects from the corpuscles, that plentifully enter at the pores, and act according to their respective natures. The like may be said of ointments, whose effects, especially on children, are sometimes very remarkable: and I have known considerable things performed by them, in an internal disease of grown men, where I should scarce have expected so much from a vegetable unguent. Indeed, by mercurial ointments a salivation may be excited; and sometimes, against the physician's will, the corpuscles of the quick-silver get so far into the body, that he is unable to bring them out again. What was said of plaisters is also applicable to *Pericarpia*, or wrist-bands; the better sort of which are often successful in stopping ague-fits: thus by a mixture of currants, hops, and bay-salt well beaten

together, both I, and several more, have been freed from tertians, and other intermittents. The argument will be likewise much strengthened, if those physicians do not deceive us, who ascribe sensible operations to things externally applied in so loose a way, as not to stick to the skin, or, perhaps, immediately touch it; which some call *Periaptia*, and *Appensa*, several whereof are best known by the name of amulets; such as quills of quick-silver, or arsenic, which some hang about their necks, or wear under their shirts, against the plague, and other contagious diseases; the blood-stones, worn by others, against hæmorrhages; and that which the women in the *East-Indies* wear for a quite contrary purpose. Now, that some of these external medicines, answer, I am persuaded by having been, one summer, subject to bleed at the nose, and reduced to employ several remedies to check it; what I found most effectual, being some moss of a dead man's skull, tho' it did but touch my skin, till the herb was a little warm'd thereby. A memorable thing of this kind was communicated to *Zwelfer*, by the chief physician to the States of *Moravia*; who having prepared some troches of toads after *Helmont's* manner, he not only found, that being worn as amulets, they preserved him, and all his domestics and friends from the plague; but that having caus'd them to be put upon the plague-sores of several persons, none of them died; but the venom of the pestilential carbuncles was thereby greatly abated, and the ulcers render'd easily curable by vulgar remedies.

As to the difficulty of conceiving, how bodies, actually cold, can emit effluvia, able to penetrate (without moistening it) a membrane of so close a texture, as a man's skin; it may be much lessen'd by considering the pores of bodies, and the figures of corpuscles. For, supposing an agreement between 'em, the effluvia of amulets may, in tract of time, easily get passage through the pores of the skin of a living body. And to make this the more probable, I will give an instance in the skin of a dead animal. But this requires a liquor, that I use in such experiments, which is made by exactly mixing flower of brimstone, powder'd sal-armoniac, and good dry quick-lime in equal quantities; and distilling 'em, by degrees of fire in a retort, till the sand is brought to be almost red-hot; for thus there will come over a smoaking spirit, which must be kept very carefully stopp'd, and which, for distinction's sake, I call the permeating menstruum or liquor; and its expirations, the permeating fumes. The experiment is this. We took a very clean piece of polish'd copper, and having wrapp'd it, either in a piece of lamb's, or sheep's leather, so that it was every way inclos'd, we held it over the orifice of the vial, that contain'd the spirit, at some distance from the liquor; whose fumes, nevertheless, quickly pervaded the pores of the leather, and operated upon the included metal; as appear'd by the deep and lasting tincture it had given to the lower surface of it; tho' the interposed leather it self, was not deprived of its whiteness, nor at all sensibly discoloured, yet smelt of the sulphureous steams that had invaded it. And the same experi-

*Boyle's Ferment
Liquor*
 $S + (NH_3 + H, Cl)$
 $+ (Ca + O)$
 $= S, H + L$

PHYSICS. experiment succeeded, tho' somewhat more slowly, when a double leather interposed between the fumes, and a new piece of copper coin.

I leave it to be consider'd, whether this may not suggest a conjecture as to that strange phenomenon, recorded by approv'd authors, of lightning which has been found manifestly to discolour money, without burning the purse that contain'd it. For, in our experiment, the steams which in a trice pervaded the leather, the most usual matter whereof purses are made, were sulphureous, as those which accompany the *Fulmen* are observed to be; and tho' these, when they invade bodies, are usually very hot, ours operated when the liquor that emitted them was actually cold. If it be said, that sometimes money has been found discoloured in the pockets of such as were not struck by the *Fulmen*, but had it only pass near them; we reply, that tho' the entire body, whether fluid or solid, if there be any of this latter kind, which the *Latin's* call *Fulmen*, (for our english word thunder-bolt seems not so applicable to a fluid) did not touch them; yet it might scatter steams enow all around to cause the phenomenon. For, a person of my acquaintance, having ascended a burning mountain in *America*, till the sulphureous steams grew too offensive; he found, amongst other effects, his money turn'd of a black and dirty colour; such as our sulphureous steams often give both to copper and silver coins. But, whether our spirits will justify my present conjecture or no, yet their easily pervading the skin of a dead animal, will, however, make it probable, that the skin of a living man may be easily penetrated by external steams, of whose approach the eye takes no notice; and whose operations may, therefore, be unsuspected. Let physicians consider, what use may be made of this observation, as to the propagation of contagious diseases, * by the contact of the infected air, distinct from the respiration of it; and by the penetration of the steams, that, issuing from several bodies, invade the skin, and may, perhaps, be able to produce, either hostile or friendly effects, not usually suspected to arise from such causes. We may add, that suspending sheep's leather in the free air, the vapours in that fluid would, I found, so insinuate themselves into the leather in wet weather, as greatly to increase its weight, of which, dry weather, whether hot or cold, would deprive it.

It may here be proper to add some instances of the penetrability of membranes to effluvia, if those be sufficiently subtil and correspondent to the pores of the other. Amongst the observations of physicians, I have met with some affirming, that cantharides have great effects upon the internal parts of the body, tho' they do not so much as touch the skin; whence their effluvia must be transmitted thro' other bodies, before they can penetrate that. *Michael Paschalius* mentions a chirurgeon, who twice voided blood with his urine; which was occasion'd by some *Spanish-flies*, that he only carried in a bag; and a physician of note mentions another

* *Bellini* has consider'd this matter, in his last propositions, *De Febris*, and demonstrat'd it possible for such effluvia to enter thro' the skin into the body. And the like has been done as to the admission of particles of other kinds, by Dr. *Wainwright*, Dr. *Keil*, &c.

person, who made bloody urine from having carrdied cantharides in his pocket; and adds, that a like case was told him by *Helidaus*, an eminent physician.

We see that in linen, the finer and more slender the threads are, the closer, and less porous, *ceteris paribus*, is the cloth; whence the thin film that lines the shell of an egg, seems to be of an exceeding close contexture; yet, even this is not impervious to some fumes; for we have stained a piece of copper through it, with those of our penetrating liquor. We also took a piece of dried bladder, and having wrapped it about a new piece of silver coin, we held it, for several minutes, over the fumes of the same liquor, but could not perceive the coin at all effected; whence we concluded the pores were too close and narrow, to give passage to the expirations of the menstruum; but presuming, that moisture would somewhat relax them, we wrapp'd up another piece of coin in a wet bladder; and applying this as before, in about two minutes, it was, on the lower surface, deeply discolour'd. But one of the most notable instances of the porosity of the internal membranes of a humane body, is that of a relation of mine, a *British* nobleman, who had, by accident, a great perforation made in his *Thorax*, at which I could directly perceive the motion of his heart. His Lordship told me, that when, with a syringe, he injected some actually warm medicated liquor into his *Thorax*, to cleanse and cherish the parts, he quickly and plainly found in his mouth the taste, and smell of the drugs, wherewith the liquor had been impregnated. And I farther learned, that as he constantly wore, upon the unclos'd part of his chest, a silken quilt, stuff'd with aromatic, and odoriferous powders, to defend the neighbouring parts, and keep them warm; when he came to employ a new quilt, the effluvia would actually mix with his breath, and very sensibly perfume it, as appear'd manifest to such as stood near him; who cou'd perceive that it proceeded not from the outside of his body. And *Galen* says, that water sweetend with honey, being injected at the orifice of wounds penetrating into the cavity of the *Thorax*, has been, in part, received into the lungs, and discharged out of the *Aspera Arteria* by coughing. Being at the dissection of a person, who had been long molested with a short dry cough, which made us expect to find something much amiss in his lungs; we met with nothing there, and were at a loss for the cause, till coming to the internal part of the chest, we discover'd, between the *Pleura* and the substance of the intercostal muscles, a certain matter, of the breadth of a crown-piece, of a roundish figure, and of the consistence and colour of new soft cheese, which odd matter was concluded to have been the remains of some ill-cured pleurisie, and to have transmitted thro' the pores of the *Pleura*, some noxious effluvia, which frequently irritated the lungs into an irregular and troublesome motion.

That not only single membranes, but even parts very much compounded are permeable, and that by liquors none of the thinnest, is manifest in the discharges made by hydropical persons, of a liquor more viscid than

PHYSICS. than water, by stool and urine, upon the operation of an hydragogue. And it is a pretty common observation, that upon the bursting of empyemas into the cavity of the chest, the purulent matter hath been voided by stool and urine: but, perhaps, it cannot be determin'd, whether this translation be made by transudation, or the entrance of the pus into the vessels; where being once admitted, it may arrive at the kidneys, or any other parts fitted to separate it. We find, however, that the lungs, sometimes, only convey things to distant parts of the body. I have often observ'd in my self, that when I had assisted in the dissection of a dog, whose blood or body was rankly scented, I, for several hours after, plainly perceiv'd that odour in the excrements I voided by siege. And a famous chirurgeon tells us, he cured a scirrhus spleen by binding over the part a sponge dipt in lime-water, which must, therefore, have penetrated not only the scarf skin, and the true *Cutis*, but the muscles themselves of the *Abdomen*, and some other interposed parts. *Galen* also observes, that bones being sometimes broken, without piercing the skin; when the callus is forming, a portion of the blood which had flow'd to the part affected, is carried to the skin, and permeates it, so as to wet and foul the dressings.

*The harder parts,
of the body per-
meable.*

Bones, horns, &c. being granted the most solid parts of the bodies of animals, I come, in the last place to shew, by particular experiments, that these also have their pores. That the nails are porous, appears from their being easily tinged with metalline solutions, particularly that of silver, in *Aqua fortis*, which can hardly be got out; and the purple spots, which I have sometimes made thereon, by little drops of the solution of gold in *Aqua regia*, to observe their growth. And the porosity of ivory may be argued from the several ways of dying it of lasting colours; for the tinctures that give them must penetrate into, and be lodged in the substance of the ivory. A solution of silver in *Aqua fortis*, will give it a dark and blackish stain, not to be washed off; and a solution of gold in *Aqua regia*, makes it of a fine purple, without heating either the solution, or the ivory: copper dissolv'd in *Aqua fortis*, stains it with a bluish colour; and without any acid *Menstruum*, I have, even in the cold, stained ivory of a fine and permanent blue, like a turquoise, by suffering a very deep solution of crude copper in an urinous spirit, as that of sal-armoniac, to dry upon it.

But to return to bones; their growth, in all their dimensions, argues their porosity: and the marrow found in them, whether it nourishes them or no, must it self be supplied by some alimental juice, that penetrates into their cavities. Nor does it seem improbable, that blood it self may be convey'd into their very substance; as I have been assured by eminent anatomists, who have observ'd blood-vessels to enter a great way into the larger bones. The blackness also that bones acquire by heat, and a peculiar kind of fatness which they afford, shew that they harbour abundance of unctuous particles, separable from the solid substance, in whose pores they must, therefore, have been lodged. The
lightness

lightness of bones, is also a great sign of their porosity; and farther, that they are corroded by tinging liquors. That calcined bones, as also those prepared for skeletons, will imbibe moisture from the air, and thereby increase in weight, I shall not much insist upon, as proofs of their porosity; because some other cause may possibly be assigned for these phenomena: I will, however, subjoyn some observations made on large ox-bones. *Nov. 15.* we weigh'd two marrow-bones, and found the one equall'd 29 ounces and half a dram; the other 24 ounces, 4 drams, and 30 grains. *Nov. 24.* The former weighed 29 ounces 6 drams, and the latter 25 ounces, 1 dram, 30 grains. *Decemb. 28.* The former weighed 29 ounces, 3 drams, 55 grains, and the latter 24 ounces, 7 drams, 39 grains. *June 7.* of the following year, the former weighed 29 ounces 2 drams, and the latter 24 ounces 7 drams. From whence, it appears, that bones plentifully imbibe the exhalations of the air, and emit them again, together with some of their own, according as the ambient happens to be disposed. And these alterations shew the bones to abound with pores; since the external steams must find pores to receive them, and the effluvia, upon their recess, leave pores behind them. And that bones themselves admit into their substance, vessels capable of conveying a nutritious liquor, seems credible by what is known to happen in that disease, which, from the country it most infests, is called *Plica Polonica*. For though one would think the hairs of men too slender to have cavities capable of containing visible liquors, yet writers of note, and particularly *Sennertus*, tell us, that in this disease, sometimes the single hairs will actually bleed, where the ends have been cut off.

But farther, even particles, neither saline nor moist, may get into the cavities of human bones; as is evident from those of mercury, where salivation hath been practis'd; whereof I have met with a notable instance in an eminent professor of physick, belonging to the famous hospital of incurables at *Rome*, who declares, that in the cavity of the bones of a venereal patient, there was found real quick-silver. This, also, hath been confirmed to me by other physicians experienced in the like cases. But, particularly, an ancient physician, very famous for the cure of this distemper, told me of a patient, who had been terribly fluxed by mercurial unctions, and coming afterwards to have one of the grinders of his lower jaw pulled out, because of the pain it had long put him to, a drop of true mercury was found in that slender cavity of the root, which admits the small vessels, from whence the tooth has its nourishment and sense. And *Eustachius Rudius* relates, that he himself saw some bodies dissected of those who had been anointed for the venereal disease, in the cavities of whose bones no small quantity of quick-silver was run together.

S E C T. II.

*The porosity
of solid bodies.*

TIS not so easy to prove the existence of pores in solid and inanimate, as 'tis in animal and vegetable bodies; however, there are some reasons which induce me to think, that the former are not destitute of them. And, first, by considering the origin and formation of several hard bodies, it will appear, that stones, and even gems themselves, were once either visible liquors, or, at least, very soft substances: and both these kinds of bodies must necessarily consist of, or abound in, minute particles of a determinate size, and shape; from whence it may be probably concluded, that such gems, and other mineral bodies, notwithstanding any hardness they afterwards acquire, retain their pores; since it is no way likely, that corpuscles of various, and very irregular figures, can be so brought together by any agents, as not to leave little interstice between them.

Another argument, to the same purpose, may be taken from the specific gravities of such bodies as the eye does not perceive to be porous. For tho' water is a body of that kind, and tho' its parts be so close, that the attempts to make a manifest compression of it have hitherto proved unsuccessful; yet we find, that stones, clays, metals, and even some woods, with a multitude of other kinds of solids, will readily sink in water, and, by consequence, are specifically heavier than it; which excess of gravity seems inexplicable, without allowing that the corpuscles of such sinking bodies, either lie closer together, or are separately more solid, than those of water: and hence we may conclude, that marble, flints, &c. are not free from porosity. The lighter metals, likewise, such as tin, iron, or steel, are above twice heavier, *in specie*, than marble; yet these are exceeded in weight by copper, which I found to be nine times; and that by gold, which, when refined, I found to be nineteen times heavier than water. Whence it seems highly probable, that iron, or steel, are so porous as to suffer metalline matter, equal to them in weight, to be contained in much less than half the dimensions of them. And that gold it self, is not destitute of pores, may appear by its dissolution in quick-silver*. If any

*Tis no new thing, that the effluvia of the load-stone should pervade the pores of all bodies, even such as are metalline; that the exhalations of the sympathy-ink should do the like at small distances, and that the sulphureous steams of the *Bolonian* stone, when newly calcin'd, should change the colour of gold into that of silver, and the colour of lartton into that of gold, tho'

closely lock'd up in a box of iron, or other metal; but M. *Homburg* discover'd, that there are substances, which manifestly, to the eye, appear to pass quite thro' the substance of a metal, without displacing its parts, making any break therein, or visibly enlarging its pores. For a salt, composed of quick-lime, distill'd vinegar, salt-petre, sea-salt, and common ful.

any should pretend, that hardness is a greater argument of the compactness of a body, and its want of pores, than its specific gravity; I add, that tho' emery, which is, indeed, much harder than marble or flint, be far heavier than thrice its bulk of water, yet that weight proceeds from the mixture of a metalline substance. And diamonds, tho' much harder bodies than emery, are so far from being the most ponderous, that, having examined them hydrostatically, I found them not much heavier than either crystal or fine glass, and not half so heavy as the lightest metals.

Another proof of this porosity, arises from the very frame and constitution of such bodies. For, we cannot suppose, that the component corpuscles of the most solid bodies, should be so interwoven, as to touch one another every way exactly, and therefore they must of necessity leave some intervals and pores between them: for there are but very few figures, which will entirely fill space; so that, considering the vast variety of other figures, it is obvious, corpuscles of such differing shapes must leave multitudes of little cavities intercepted between those parts, which do not every where touch one another. And even those few mathematical figures, said to fill space, do it rather in a geometrical, than a physical sense; because such can never actually exist in matter: for no art could polish a cube of marble, for instance, so that no small scratches should be left on its surfaces, to hinder their perfect contact: and marble it self abounds with internal pores, as may be rationally conjectured from the specific gravity of it, in comparison of gold and lead.

Having thus dispatched the arguments *à priori*, we come to our experiments and observations, which confirm the same doctrine *a posteriori*. Of these, some relate to solid bodies, of a less specific gravity; some to fossils, presumed to have no metalline parts; some to minerals, which are thought to participate of a metalline nature; some to metals; and some to glass. To begin with the first: besides other considerations, the porosity of wood is manifest from this experiment. We took a wooden shooting-trunk, and having closely stopp'd one end of it, we poured quick-silver in at the other, till it reached to a considerable height; when, the lower parts, assisted by the weight of the incumbent ones, issued out at the pores of the wood on all sides, in great numbers of drops, much after the manner of quick-silver strained through leather. But, perhaps, the great weight of the quick-silver had a considerable share in the event. And this observation is applicable to the following experiment; when having, by the help of

*The porosity
of wood.*

fulphur, will readily, as he shews, and of a sudden, pass, in this manner, thro' an iron crucible set in a strong fire, as water passes thro' paper; and a bituminous, metalline matter, or cinnabar of silver and antimony, will pass thro' a thin plate

of silver, and turn it in the parts, both internal and external, thro' which it run, of the colour of lead, without causing any farther change therein. See *Memoir. de l'Academ. A. 1713. p. 409.*

PHYSICS.

my pneumatical engine, withdrawn the air from one side of a round piece of a board, the air, on the opposite side, press'd so strongly against the surface, as to make way through the pores of it, and get into the cavity, whence the other air had been extracted. This seem'd the more surprizing, because the board, thus permeated, was of strong wood, and considerably thick. But it may here suffice, that when wood is reduced to a certain thinness, it will easily give passage, even to visible, odorable, and tinging corpuscles. For (1.) the fumes of our penetrating liquor, tinged a copper half-penny through a deal-shaving, which did not, when held against the light, discover any perforation. (2.) The same fumes manifestly tinged the same half-penny, thro' two such shavings of deal, laid upon each other, in less than one minute. (3.) And in about one minute, these fumes tinged it again, thro' three such shavings of deal, very visibly, but not so strongly as in the first, or even the second experiment; and these trials were made without heat.

Of earthen vessels.

That many earthen vessels are porous, appears from their being soaked thro' by oil; some by solutions of nitre, and other salts; and there are very few crucibles, not even the *Hassian*, that will long keep salt of tartar in fusion, without being penetrated by it. I have heard it complain'd of, in the distillation of corrosive materials, as vitriol, and saltpetre, with strong fires, in the earthen vessels commonly made use of, instead of retorts, that a considerable quantity of the finest spirits escape quite thro' the vessel; so that many ounces are found wanting of the first weight of the matter. And tho' I have observed some earthen bottles, to be hard enough to strike fire with steel; yet I have been assured, that these may have their pores pervaded by spirituous liquors. And a person, curious in making cyder brisk and spirituous, assured me, that it would permeate the very substance of stone-bottles; as appeared both by the taste of that on the out-side, and the less quantity within: and the like observation was confirm'd to me by an eminent physician, who being a great lover of brisk cyder, used to bottle it up carefully. And tho' good *Hassian* crucibles are very closely compacted, yet having dissolved silver in *Aqua fortis*, and I kept it a while in fusion, among quick-coals, it would, without cracking the crucible, soak into it, and pass the pores of it in many places; a multitude of minute globules of pure silver, like so many little drops, appearing on the outside of the vessel.

Of natural stones.

In some part of the *West-Indies*, they have a stone, whereof they make large vessels to strain water through; and one of these was sent me as a present; which I found to answer, tho' it was considerably thick. And if the hypothesis, concerning the transparency of bodies from a rectitude of pores be just, we may draw a very probable argument for the porosity of stones from the phenomena of that odd gem, call'd *Iculus mundi*; for this, when dry, and in the air, is opaque, almost like a polished piece of white amber; but if put into fair water, it will gra-

gradually become quite transparent. Now, according to that hypothesis, the pellucidness, which this stone acquires in water, may be accounted for, by saying, that the liquor getting in at the crooked pores of the stone, does, for the time, rectify them, and make them pervious to the streight rays of light; as white paper, being moisten'd with oil, has its pores so changed, as to make it almost transparent; but upon the absence of the imbibed particles, the pores becoming crooked again, reflect those rays of light they should transmit. And what countenances this doctrine, the *Oculus mundi* has been found to weigh more in a nice balance, when taken out of the water, than before it was put in. PHYSICS.

There appears so great a difference, in many qualities, betwixt stones and metals, that it is very probable, when the corpuscles of both come together into one mass, they will not touch one another so, as not to leave interstices between them; whence I have been induced to think, that several stones are not void of porosity. For I have obtained metalline parts, both from granats, and emery; tho' the latter be so exceeding hard, that it is usually employed by artificers to work upon iron, and steel; and to cut not only rock crystal, but several gems, harder than either that, or steel. Hence, also, we may probably infer the porosity of many artificial gems, made by fusion; for to give these the colour of sapphires, topazes, amethysts, &c. we add to the matter, either some prepared metal, as calcined copper, calx of gold, &c. or else some mineral, as zaffora, and *Magnesia*, which abound in metalline parts. Nay, I have sometimes given the colour by natural gems, as granats; tho' to shew that the colouring, which the mass received from these, proceeded from the metalline corpuscles, that lay hid in the tinging matter, the colour produced was not that of the gem, but very different. And this experiment makes it also probable, that even natural gems are themselves porous; since they are made up of such differing ingredients as stony and metalline corpuscles. From the same foundation we may, likewise, deduce the porosity of marcasites; many of which I have observed to be not only so hard, as plentifully to strike fire by collision with steel, but more ponderous than many rich ores; for they usually contain more or less of copper, iron, combustible sulphur, a corrosive salt, and a certain fixed substance, which I found to differ from true earth. I might here, also, deduce the porosity of the load-stone, as hard and solid a body as it is, from its effluvia, and heterogeneity. But the porosity of marble, and several other stones of like texture, appears from their solution by various corrosive menstruums, and some of them even by vegetable liquors, as the juices of lemons and barberries: but a more satisfactory proof arises from the staining of white marble, without any fretting liquor, or spoiling the texture of it, as I my self have try'd. For an excellent red colour may be made to soak into a piece of white marble, almost as oil sinks into leather, without impairing the solidity of the stone, which, too, will be capable of as fine a gloss as before. Some other colours might

PHYSICS.

might, also, be brought to soak into marble. An artificer, whom I introduced, presented the king with an *Andromeda*, whose colours were very vivid; and to satisfy his majesty, that the fine red was not a mere varnish, I purposely broke a marble plate, in whose fragments, the pigment had sunk to a considerable depth: and a fine plate of such white marble, with the penetrating pictures of coloured flowers upon it, I yet keep by me; and some utensils of the same kind of stone, as hafts of knives, salt-sellers, &c. I have known to last for several years. But there is an experiment, that pleads much stronger for the porosity of solid bodies, than even this of staining marble. For, in *Italy*, some goldsmiths have a way of imbuing fragments of rock-crystal, which is a body much harder than marble, with various colours, so as to make them worth setting in gold rings. Upon information hereof, I attempted to tinge crystal, with indifferent success; but suspect that the vehement heat I employ'd made small cracks in several parts of the stone, wherein the pigment enter'd.

Of metals.

That metals are porous, may be proved by their solution in appropriated menstruums. But it seems more considerable, that even gross bodies will penetrate them without melting: and this we have effected by a cementation of copper plates with common sulphur, laid *Stratum super stratum*, in a cover'd crucible, exposed to a proper degree of fire; the plates being thereby quite altered in colour, and texture; some of them appearing of a dirty, others of a fine violet or blue colour. They were, also, generally render'd so brittle, that it was very easy to break them with ones finger, and reduce them to powder. And many of them appeared to have been horizontally divided into two parts, with a manifest cavity between them. I could, likewise, plainly discern a multitude of fibres, reaching from one of the flat sides of the plate to the other, and running parallel with one another; which circumstances sufficiently argue, that they were pierced quite thro' by the sulphur: besides, they, also, gained in weight by the process, appear'd much thicker, and, laid upon quick coals, yielded a blue flame. By the like experiment we found refined silver to be penetrable by sulphur, which will also calcine tin, lead, and iron. Metals are, also, penetrable by prepared arsenic. But these operations with it are dangerous. There is a still farther way, without the help of salts, sulphur, or arsenic, to make a solid and heavy body soak into the pores of copper, and give it a durable golden colour, that shall sink considerably below the surface.

A farther proof, to this purpose, is afforded us by the impregnation of solid bodies with odorous corpuscles, as is practised on sword blades at *Damascus*, and on many other hard substances by the *Indians*. An acquaintance of mine had a watch, whose metalline case strongly retained a perfume, without sensible diminution. And, indeed, since both arsenic, and common sulphur, may be incorporated with some metals; it seems not impossible, that scented substances should be admitted into the pores of metalline bodies, and be volatile enough to have their more subtile parts fly

fly off in odorous exhalations. I have made a metalline composition, which looked like gold, and of which, I caused a ring to be cast, that retained so many invisible mercurial corpuscles, as to prove medicinal.

An inquisitive nobleman, who had lived in several parts of *Afric*, told me, that some descendants of the *Granadine Moors*, made the best arms he ever met with; of whom he had a sword-blade admirably perfumed, as also the barrel of a fowling-piece.

Glass being reputed the most compact body we know, it will be expected of glass. I should here say something about the porosity of it. And to proceed with some method, I shall throw what I have to offer upon this head into two distinct propositions, and annex observations to them.

P R O P. I.

It is very probable, that glass may be deeply penetrated, even by visible and tangible bodies.

Having long kept a certain spirit of salt in a vial, I at length found the glass crack'd, and most of the liquor run out; but before this happened, it had so far corroded the inside of the glass, that in some places it was become as thin as paper: and this part, which yet continued glass, was lined with a much thicker white substance, that stuck to the sides of it, and looked and tasted like a kind of odd salt; which made me conjecture, that it proceeded from the substance of the glass, which consists of an alkali, as well as of sand corroded by the saline spirits of the menstruum, and coagulated with them into this odd kind of concrete: and 'twas remarkable, that the upper part of the vial, to which the menstruum did not reach, was not corroded, nor altered, tho' the operation of the liquor reached as high as the liquor it self: and an experienced chymist, assured me, that the like thing happened to him. I had also another vial corroded by a distilled liquor of vitriol, that contained more phlegm than oil: but some acid menstrooms will not corrode so readily, if they are very strong, as when diluted with a convenient quantity of water. Thus to oil of vitriol it self, when employ'd to make *Vitriolum Martis*, we add water, that it may the better dissolve the iron. And it shou'd seem as if that vitriol had some peculiar faculty of penetrating and fretting glass; for distilling a pound of *Dantzic* vitriol, and a pound of sea-salt, when the former had been very lightly calcined, and the latter decrepitated; we afterwards found the heat had here and there melted it, and that the fluxed *Caput mortuum*, had corroded the glass, fetching off films from it; and those parts which did not appear to the eye thus manifestly wasted, seemed, by their great brittleness, to have been penetrated, so that their texture was spoiled by the saline, and vitriolate corpuscles.

P R O P.

The POROSITY of BODIES.

P R O P. II.

Common glass is not usually pervious to chymical liquors, tho' strong and subtile, nor to the directly visible, or odorable expirations of bodies; tho' absolutely speaking, it is pervious to some corporeal substances.

As for the first part of the proposition; it is manifestly agreeable to common experience, that in well stopp'd vials, the most subtile and piercing menstrooms, whether acid, urinous, or volatile, may be kept. And these, tho' in distillation, they are often greatly agitated, and perhaps subtilized by heat, yet if the luting, that joins the receiver to the retort, be very firm and close, will often burst the receivers to pieces; which probably would not happen, if the spirits could insinuate and press thro' the pores of glass. It may be pretended, that such vessels are thick; but having procured very fine bubbles blown extremely thin, I could not find, that either dry salt of tartar, would relent in one, that long lay under water, or that strong spirit of sal-armoniac, would penetrate another, which we kept for a great while immersed in it. These, and some other trials, have made me very diffident of the experiments delivered by some men, as to the perviousness of ordinary glass vessels to chymical liquors; as that mercury and *Aqua fortis*, being digested together in a bolt-head, may, by rubbing the outside of the glass, be made visibly and palpably to transude: which experiment I purposely made with care, but without success. After all, it must be remembred, that I here speak of what usually happens: for in some extraordinary cases, I do not absolutely deny, that the general rule may admit of exceptions; which are likeliest to take place, when the peculiar texture of the glass is slight; or when the bodies to pervade it, are vehemently agitated by heat; or when, besides both these, their particles chance to have a particular fitness to that particular glass, they are to pass through. I have seen a glass so soft, that vessels of it would be manifestly prejudiced by liquors, not considerably sharp or corrosive, if they were put in very hot. I have also heard another sort of glasses complained of by distillers, as subject to be injured by corrosive liquors. And I once knew a physician, whom several chymists suspected to have the philosopher's stone, but debating his principles freely with him, he own'd he had been mistaken, and frankly gave me an ingenuous account of his proceedings, wherein the principal thing which dazzled him, was, that he had reduced the matter he wrought upon, real gold, to such a degree of fusibility, and subtilty, that when he gave too strong a fire, as mistake or curiosity made him several times do, the finer part of the metal would sweat through his glasses, and stick sometimes to the outside of them, and sometimes to the neighbouring bodies. I objected, that he might here be mistaken, and that what he thought had come out by transudation, rather issued at some small unheeded crack; but he replied, that he had made the observation so often,

often, and with such care, as had fully satisfied him it was a real penetration of the glass, by the attenuated metal. But whatever be judged of this matter, having once distilled spirit of harts-horn, with a very strong fire into a large and thick receiver, but of a coarse kind of glass; it appear'd that the glass it self was penetrated by some fumes, or subtile liquor, that settled, in strongly scented drops, on the outside of it. But such instances being very rare, and happening but in some cases, or conjunctures of circumstances, they affect not the truth of the first part of our proposition, in the sense wherein it is delivered. And as to the second part, which asserts the perviousness of glass to some corporeal substances, it appears from the free ingress and return, which our sealed thermometers shew, the atoms or corpuscles of cold and heat, are allow'd to make thro' the pores of glass, that contains the rising or falling tincture, or other liquor. And the effluvia of a load-stone will invigorate steel in hermetically sealed glasses: nay, the effluvia of the earth, are readily transmitted thro' glass, and will operate on iron, in vessels hermetically sealed. If light be, as probably it is, either a subtile, and rapidly moving body, or at least requires such an one for its vehicle, it is possible for a body, without difficulty, to pass through the pores of glass; since, by the help of light, we can clearly see the dimensions, shapes, and colours of objects included in glasses. And bodies, far less subtile than those which constitute or convey light, may permeate glass, if they be assisted by an impetuous motion, or a brisk impulse; as I have found by the increase of weight in some metals, exposed, in hermetically sealed glasses, to the action of flame. And, without any sensible heat, I think it not impossible, that glass should be freely penetrated by some kind of corpuscles, which happen to rove about in the air; for, having in two or three vials, closely stopp'd, kept a certain transparent, colourless liquor, it would by fits acquire, and lose an high colour; tho' I could not reasonably impute the changes to any other cause so probable, as the admission and exclusion of some particles, which at that time happened to swim in the air, and now and then to invade, or desert the liquor.

There is another argument for the porosity of glass, to be drawn from some of the ways of colouring it, for the windows of churches, and other buildings. For tho' it be, in some cases, rather painted, or superficially enamelled, than tinged; yet, in others, the pigment appears to pierce a little beneath the superficies of the glass; and the yellow colour will not only go deeper, but sometimes seems to penetrate the whole glass from side to side. The methods of staining it, having been hitherto known but to few, the artificers are shy of their secrets; tho' we know, in general, that it is done by covering the plates with mineral pigments, laid on beds of beaten lime, or some other convenient powder, and kept for several hours in a strong fire, yet not strong enough to melt down the plates; by which means the pores of the glass being much opened, and the pigments likewise agitated, and some of them, as it were, vitrified with it, they are made either to pierce into the plate, or at least to stick very closely to it.

The way of colouring glass.

PHYSICS.

But to shew, more particularly, that glass is porous, we took silver calcined by burning sulphur upon it in the open air, and laid it upon a piece of glass, and placed it, with the pigment uppermost, upon a few quick coals to heat a while; we gave it about such a degree of heat, as might make, and keep it red hot, without fusion; and then suffering it to cool by degrees, we found that the glass had acquired a yellow, and almost a golden colour, not to be washed off, or taken away without such scraping as would spoil the glass itself. And, by the way, it is remarkable, that if the fire be made too strong, the dyed glass, when held against the light, appears of a golden or yellow colour; yet when held from the light, looks blue. Whether the gold-colour, produced by silver, favours the hopes of those chymists, who work on that metal, upon presumption, that it is but unripe gold, I must not here examine. But, since yellow is not the colour of silver, the yellowness, acquired by our glass plates, seems to argue, that the substance of the particles of the silver has penetrated into the glass; there appearing no way so ready to account for this change of colours, as by supposing the particles of the silver to be wrought on by the fixed salts, and other fine parts of the glass; since we know, that metals may afford differing colours, according to the saline and other bodies that work upon them; as copper with spirit of urine, which abounds in volatile salt, gives a deep blue; with spirit of salt, a fair green; and with *Aqua fortis*, a colour that participates of both. And in making glass of lead with minium and white sand, or crystal, the glass itself, if well prepared, is usually of an amethystine colour: but if a due proportion of calcined copper be put to it, this metal will not communicate its own redness to the glass, but so a good green, that sometimes pieces of this glass, such as we have caused to be cut, and set in rings, might, amongst those who judge of stones only by the eye, pass for tolerable emeralds.

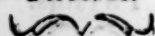
Whether the
art of staining
glass be lost.

It may here be asked, whether glass can be tinged quite through with a red? and whether the art of dying glass be now altogether lost? We can answer the first question in the affirmative; tho' the red tincture being communicated not properly by mere penetration of the pigment, but by the incorporation of it with the glass, or its materials, by the help of fusion, I think the experiment of no great use in our present inquiry: and as to the second question, I wish it may be cautiously stated. For upon the burning of St. Paul's Cathedral in London, many pieces of the red glass were found broken, and scattered about, some of which I procured; when I came to examine them narrowly, I was confirm'd, that the redness did not penetrate the whole glass; for, tho' in other postures no such thing could be discerned, yet when I so held it, that the surfaces of the plate lay in a level with my eye, between it and the window, so that the broken edge was next my eye, I could plainly see the lower part of the plate to be of ordinary uncoloured glass, upon which there lay a very thin plate or bed of a transparent red pigment, which, it was not impossible in some places to scrape off. But to return to those colorations, that seem

to

to penetrate the pores of glass; I had once occasion to distil, in a small retort, some gold amalgamed with such a fine and subtile mercury, that being put to the metal in the cold, they presently grew hot together: and in the distillation of this uncommon mixture, I found the matter had, before it flew away, permanently stained about an inch in diameter of the bottom of the glass, with a colour, like that of the better sort of turquoise; but being viewed, when it was interposed between the window and the eye, it appeared of a somewhat golden colour. And an industrious person, having united gold with a particular quick-silver, by my direction, he kept them in digestion for some months; when, the fire having been immoderately increased, the sealed glass burst with a frightful noise; and the included amalgam was so strangely dissipated, that scarce the least fragment of it could be recovered. But the state of decoction having continued a long time, it seems the matter was subtilized enough to have a notable operation on the glass. For tho' the upper part were blown off, and shattered into pieces, yet the lower escaped tolerably whole; and I took notice, with delight, that it was tinged throughout of a fine and glorious red, hardly to be matched by that of rubies.





T H E INTESTINE MOTION O F T H E PARTS of SOLIDS.

Rest, what?

*No bodies at
absolute rest.*

TH E term rest, applied to a visible and entire mass of matter, commonly signifies such a state of it, wherein no motion, either of the whole, or its particles, appears to the eye. And in this sense several bodies may, doubtless, be said to be at rest.

But there is also a more strict and philosophical kind of rest, which we may call absolute; importing the continuance of a body in the same place precisely; with an absolute negation of all motion, tho' ever so slow or imperceptible. And in this rigid sense of the word, perhaps no bodies in the universe are at rest.

On the *Epicurean* hypothesis of the world, the atoms that compose all the parts thereof are in perpetual motion. And if we admit the *Cartesian* scheme, a subtile matter constantly passes thro' the pores of the most solid bodies; and therefore, in all probability, is continually shaking the minute parts of those that seem to be at rest; the eye taking no notice of the motion: as a gentle wind, stealing thro' a grove, will not, to a remote spectator, appear to stir the leaves and twigs of the trees.

Several fluids, which appear to be continued masses of matter, and to rest as much as the vessels that contain them, yet have their constituent parts in a various actual motion, tho' slow and unperceiv'd.

That there may be, likewise, such a motion in the minute parts even of silver and iron, appears by the heating of those metals almost red hot; when tho' the eye discerns no motion, the touch will be sufficiently affected by it; water thrown upon them in that state will be made to boil; and bare agitation, without the assistance of fire, will enable these metals to exhibit the like phenomena.

If a steel spring be forcibly bent, and kept, for a moderate time, in that posture, 'twill, upon the removal of the force, restore it self; but if detain'd very long in that position, it gradually loses its motion of restitution,

tion; which shews the power of some secret tho' familiar agents in nature; and that, where there is a continual endeavour of the parts of a body to put themselves into another state, the progress may be much slower than we usually imagine. And this is farther manifest from the durable magnetic power gradually gain'd by a rod of iron, standing for a long time, perpendicularly, exposed to the air.

Lignum Vita, tho' it seems to be the most solid wood we know, yet I am inform'd from good hands, that it requires a great length of time to season it; so that it ought to be kept for twenty years before 'tis fit for some purposes; otherwise the heat of the sun will crack and cleave it to pieces. And in turning this wood, cavities of several sizes have been found fill'd with considerable quantities of gum. Now, since so solid a body requires so long a time to season it, that is, to give it a due compactness; and since this seasoning seems to consist in the gradual avolation of the looser, aqueous and more fugitive parts, whereby the remaining solid ones are brought closer together; it follows, that even in the internal parts hereof, there must be a motion, tho' too slow to fall immediately under the senses. And, if the gum above-mention'd be generated, as 'tis probable, after the tree is cut down; then a gross, tenacious substance may penetrate one that is very solid and inanimate; which cannot happen without an intestine motion among the parts of the wood, and, probably, a wonderfully slow one of those of the gums.

An intestine motion in the parts of wood.

Nay, wood of a much looser texture will require a longer time to season it than guaiacum. For ancient musicians and makers of musical instruments declare, that some lutes will require forty years to bring them to their due tone; if the wood be thick, and other circumstances not very favourable. And I have been inform'd, that there are some famous instruments of the same kind, which, to attain their full seasoning and best sound, require the space of fourscore years.

The walls, also, of some buildings, attain not their due hardness and solidity in less than forty years, or more; whence the motion of their internal parts may well be argued. And there are stony as well as metalline marcasites, which have so great a motion in their internal parts, that, if exposed to the air, they will manifest a vitriolate efflorescence on their surface, and, in tract of time, burst to pieces; of which I have seen some instances. And this vitriolate efflorescence will, as I have try'd, happen on the internal surface of a broken marcasite, as well as on the external. But what is more extraordinary, a gentleman, of my acquaintance, had a turquoise stone, wherein were several spots of different colours, which seem'd to him, for many months, to move slowly from one part of the stone to the other. And, having the ring, wherein 'twas set, put into my custody, I drew pictures of the spots at different times; and by comparing several of the draughts together, it evidently appear'd that they shifted their places, as if the matter whereof they consisted made its way thro' the substance of the stone. And, as far as we observed, the motion of these spots was exceeding slow and irregular. An experienced jeweller,

Stones.

PHYSICS.

jeweller, likewise, assured me, that, in a few turquoise stones, he had observed two different blues, in different parts of the same stone; and that one of these colours wou'd, by slow and imperceptible degrees, invade, and, at length, overspread that part of the stone, which the other before possess'd. And the same gentleman who lent me the spotted turquoise, also shew'd me an agate-haft of a knife, wherein was a certain cloud, which an ingenious person had for some years observed to change its place in the stone.

Diamonds.

Glass and diamonds are generally esteem'd bodies of the closest and firmest texture that nature and art afford. If, therefore, we can shew an intestine motion in these, it will hardly be denied in softer substances. Now, diamonds easily become electrical; and some of them will, by being rubbed upon a cloth, be brought to shine in the dark; in both which cases a change of texture, even of the internal parts, is required: and the friction producing this change, doing it immediately by putting the parts of the stone in motion, it seems that a very moderate force may cause an intestine motion, even in the internal parts of diamonds. And, perhaps, more hidden agents may make impressions upon these hardest of bodies. In a diamond-ring which I constantly wear, I have often seem'd to observe a manifestly greater clearness and sparkling at some times than at others; when I cou'd ascribe neither to any manifest cause. And in a rough diamond of mine, I have in a short time observed considerable variations in its degrees of electricity; tho' no manifest cause appear'd of so surprizing a phenomenon. A very ingenious lady, also, who wears abundance of diamonds, assur'd me, she had often observed the like alterations in some of them; which wou'd sometimes sparkle more, and sometimes be far more dull than ordinary, tho' neither the weather nor the foulness of the stones cou'd occasion it. And I have seen a cloudy *Hungarian* diamond, made clear by lying for some time in a cold liquor; and the owner affirm'd it wou'd gradually lose more of its cloudiness, the longer it was detain'd therein. And what I saw my self, sufficed to shew, that changes are producible even in the inward parts of such diamonds, by agents acting without any apparent violence.

And if, as 'tis possible, diamonds may be generated from time to time in the bowels of the earth, perhaps they may, after they seem perfect, and fit for rings, long continue to have an insensible motion thro' the whole of them; whereby the component particles of each may be disposed into a more convenient texture, to constitute an extremely hard body: for diamonds are not equally hard. An expert lapidary assures me, he finds some of them so soft and brittle, that he refuses to cut or polish them, lest they shou'd break upon the mill. And a late *French* author, giving an account of the *Eastern* diamond-mines, tells us, that the stones of the third mine are very clear, and of a good water, but must be ground with stones of the same mine, because with those of another they wou'd be broken to pieces; for they easily break upon the wheel; so that such as are not versed in them, may be easily deceiv'd therein. This
author

author farther adds, that upon most of the diamonds of the second mine, there appears a kind of greasiness, which seems to proceed from some insensible effluvium of the stone, condensed by the air on the surface: which conjecture might be examin'd by an exact balance. A curious lady, very nearly related to me, has a fair ruby, set in a rich ring, which sometimes yields a more vivid fire than ordinary, and at others is manifestly more dull and cloudy, tho' this be in no wise owing, as she expressly assured me, upon repeated observations, to the cloudiness of the weather, or any superficial foulness of the stone.

And glass.

Upon inquiry among the makers of telescopes, and such as use them, I found that the *Venice*-glasses employ'd in them, wou'd sometimes crack, spontaneously, whilst they were in plates, and sometimes after they were ground and polish'd. And I have suspected that some saline corpuscles, more numerous than the nature of the glass requires, may, by slow and imperceptible degrees, so tend towards the surface of it, as either to get out at its pores, or crack, or burst the glass, in attempting to force a passage outwards. And I am inform'd by such as deal much in glass, that there will sometimes, especially in the winter and very moist weather, be a kind of efflorescence, of a saltish taste, manifestly discernable upon the surface of their glasses. I have, also, a thick glass cup, that was, soon after the making, so flaw'd with a multitude of little cracks, that at a distance it look'd white, and not transparent. I have, sometimes, also, had vessels, and other bodies of glass considerably thick, which, of their own accord, have suddenly, and with noise, broke to pieces, tho' some of them had been well nealed. And the like, upon inquiry, I find has frequently happen'd to glassmen and others; particularly, several pieces of large strong looking-glasses, broke in this manner, have been shew'd me, by the maker, who assured me this wou'd sometimes happen, after they had long stood in his shop; when they wou'd fly asunder with such violence, as to break some adjacent plates, tho' thick and strong. Nay, this disposition to break, has continued in some sorts of glass for several years; particularly in a parcel that had lain by for above four years; which when the master of a glass-house came, as he told me, at length to open, and range in order, a fourth, or a third part of the whole number, soon after crack'd spontaneously. Now whether we solve these phenomena on the atomical or *Cartesian* hypothesis, there will appear to be an intestine motion in glass; which being easily made electrical by friction, and as easily crack'd by applying a hot iron first, and then cold water to a part of it, farther confirms this doctrine. Glass, also, swells considerably, or alters its figure after 'tis blown, and seems to be sufficiently cooled. For when white glasses are blown into a mould, they cannot, when cold, be put again into the same; and require the cells of guard-vials to be larger than the mould. From the whole, I will not positively infer, there is no such thing as absolute rest in nature, but, probably, there is not; since we have not found it in those bodies, where it might, with reason, be the most expected.

CONSIDERATIONS
UPON THE
NATURAL
AND
PRE-TERNATURAL STATES
OF
BODIES,
Especially the AIR.

*The common
notion of the
natural and
preter-natural
states of bodies,
obscure, unjust,
and liable to
be misapplied.*

THE famous distinction between the natural and pre-ternatural or violent state of bodies, as well inanimate as animate, has been universally admitted; and hypotheses and reasonings are daily, without the least scruple, founded upon it, as if it were most certain, that nature had purposely framed bodies in a determinate state, and were always watchful that they should not by any external violence be put out of it.

But notwithstanding so general a consent in this point, I confess, I cannot yet be satisfied about it, in the sense wherein it is usually taken. 'Tis not that I believe, there is no sense wherein a body may be said to be in its natural state; but that I think the common distinction of a natural and violent state of bodies has not been clearly explained, and considerately settled; and that it is not only ill grounded, but oftentimes ill applied. For, since whatever state a body is put into, or kept in, it obtains or retains that state, according to the universal laws of nature; in this sense, the body propos'd must be in a natural state: but, upon the same ground, 'twill be hard to deny, that those bodies which are said to be in a violent state, may, also, be in a natural one; since the violence, they are presumed to suffer from external agents, is, likewise, exercised no otherwise than according to the established general laws of nature. 'Tis true, when men

look

look upon a body as in a preter-natural state, they have an idea of it different from that which they had whilst they believ'd it to be in a natural one: but perhaps this difference arises chiefly from hence, that they do not consider the condition of the body, as it results from the universal laws settled among things, and relates to the universe; but estimate it with regard to what they suppose is convenient or inconvenient for the particular body it self. However, it seems to me, that the determining a body to be in a natural or preter-natural state has much more in it, either of casual, or of arbitrary, or both, than they are aware of. For, we often think a body to be brought into a violent state, not because the former was really less so, but because there is a notable change made in it, by some agent, which we also take notice of; whereas, before the action of that agent, if the body were under any violence, 'twas exercis'd by usual, but unobvious agents; tho' perhaps, their action were not less, but disregarded more. And sometimes, also, no more is to be understood by a bodies being forc'd from its natural state, than that it has lost what it had immediately, or a considerable time, before some notable change.

Now, matter being destitute of sense and appetite, cannot be truly and properly said to affect one state or condition more than another; and consequently has no true desire to continue in any state, or to recover it when once lost: and inanimate bodies are in their state, not as the material parts they consist of chose or desired to make them, but as the natural agents, that brought together and rang'd those parts, actually made them. Thus, a piece of wax is unconcern'd, whether you give it the shape of a sphere, or a cone; and whether, when it has that form, you change it into any other; the matter still retaining, without willingness or unwillingness, because without perception, that figure or state which the last action of the agent determined it to, and left it in.

The most usual instance produced to shew, that a state is natural to a body, and that being put out of it, by external causes, it will, upon the cessation of their violence, be restored thereto, is, that water being heated by the fire, returns to its native coldness, as soon as that adventitious heat vanishes; and so when, by an excess of cold, it is congeal'd into ice, it, upon a thaw, loses that preter-natural hardness, and recovers the fluidity naturally belonging to it: and the same may be, likewise, said of butter, which, being melted by external heat into a liquor, does, upon the cessation of that heat, grow a consistent body again. But as to the coldness whereto water heated by the fire, returns when 'tis remov'd thence, it may be said, that the acquired heat consisting but in the various and brisk agitation of the corpuscles of the water by an external agent, it is no wonder, when the agent ceases to operate, that the effect of its operation should cease too, and the water be left in its former condition; whether we suppose it to have been heated by the actual pervasion of the cor-

Whether water be not as properly thaw'd ice, as ice is frozen water.

PHYSICS.

puscles of the fire, which by degrees fly away into the air; or that the heat proceeds from an agitation imparted by the fire to the aqueous corpuscles, which must, by degrees, lose that new agitation, by gradually communicating it to the contiguous air and vessels; so that, if the former agitation of the particles of the water were, as is usual, much more languid than that of our organs of feeling, in which faintness of motion the coldness of the water consisted, there will be no need of any positive internal form, or any care of nature to account for the waters growing cold again. This may be confirm'd by considering what happens to ice, which is said to be water brought into a preter-natural state by an excess of cold. For, I doubt, 'twill not be easily demonstrated, that, with regard to the nature of things, and not to our arbitrary ideas of them, ice is water preter-naturally harden'd by cold, and water not ice preter-naturally thaw'd by heat. For if you urge, that ice, left to it self, will, when the frigorific agents are removed, return to water; I answer, that, not to mention the snow and ice that lie all the summer long unthawed upon the tops of the *Alps* and other high mountains, I have learn'd, by inquiry, purposely made, from a physician, who for several years practised in *Muscovy*, that in some parts of *Siberia*, the surface of the ground continues more months of the year frozen, by what is call'd the natural temperature of the climate, than thaw'd by the heat of the sun; and that a little beneath the surface of the ground, the water, which chances to be lodged in the cavities of the soil, continues frozen all the year; so that, when in the heat of summer the fields are cover'd with corn, if you dig a foot or two deep, you shall easily find ice and a frozen soil: whence a man born and bred in the in-land part of that country, and inform'd only by his own observation, may probably look upon water as ice violently melted by the sun, whose heat is there so vehement, as to ripen the harvest in less time than in our temperate climates, will be easily credited.

Whether a liquid or a consistent form, be the natural one of butter, &c.

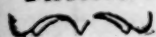
On the other side, we in *England* look upon melted butter, as brought into a violent state by the operation of the fire; and therefore think that, when being remov'd from the fire, it becomes a consistent body again, it has but recover'd its native constitution. But there are several parts of the *East-Indies*, and, I doubt not, of other hot countries, where the inhabitants, if they should see consistent butter (as sometimes by the care and industry of the *Europeans* they may do) they would think it brought to a preter-natural state, by some artificial way of refrigeration. For in those parts of the *Indies* I speak of, the constant temper of the air being able to entertain as much agitation as suffices for fluidity in the parts of what, in our climate, would be butter, it were in vain to expect, that, by being there left to it self in the air, it should become a consistent body. And I have learn'd,

learn'd, by diligent inquiry, of sea-men and travellers, both *English* and others, who were eye-witnesſes of what they told me, that, in ſeveral parts of thoſe hot regions, butter, unleſs by the *Europeans*, or their diſciples, purpoſely made in the cold, remains fluid all the year long, and is ſold, or diſpens'd, not as conſiſtent bodies, by weight, but as liquors, by meaſure. To ſtrengthen this obſervation, I ſhall add, that a learned man, who practis'd phyſic in the warmer parts of *America*, affirm'd to me, that he met, in ſome places, with ſeveral druggs, which, tho' they there ſeem to be baſams, as turpentine, &c. are with us, and retain'd that conſiſtence in thoſe climates; yet when they come into our colder regions, harden into gums, and continue ſuch both winter and ſummer. On the other hand, inquiring of a traveller, verſ'd in phyſical affairs, about the effects of great heat in the in-land part of *Africa*, where he had lately been; he told me, among other things, that roſin of *Jalap*, which, when he carried it out of *England*, was of a conſiſtence not only dry, but brittle, did, when, and a while before he came to *Morocco*, melt into a ſubſtance like turpentine; ſo that ſome of it which he had made up into pills, would no longer retain that ſhape, but remain as it were melted all the while he ſtayed in the neighbouring countrey; tho' when he came back to the borders of *Spain*, it return'd to its former conſiſtence. And having my ſelf conſider'd ſome parcels of gum *Lacca*, newly brought aſhore from the *East-Indies*; tho' it be a hard and ſolid gum, yet I found by ſeveral inſtances, that, in paſſing thro' the torrid zone, various pieces of it, notwithstanding the ſhelter afforded it by the great ſhip it came in, had been, by the heat of the climate, melted, and made to ſtick together; tho' afterwards they regain'd their former conſiſtence, but not altogether their former colour. And I learn'd from a particular acquaintance of mine, who brought me ſeveral rarities out of *America*, that, having at the place where 'twas made, among other things furniſhed himſelf with a quantity of the beſt aloes, he obſerved it to be, whiſt he ſail'd thro' very hot climates, ſo ſoft, that, like liquid pitch, it would often have fallen out of the wide-mouth'd veſſel wherein he kept it, if he had not, from time to time, been careful to prevent it: but when he came within a hundred leagues of the coaſt of *England*, it grew hard, and ſo continued; tho' this were in a very warm ſeaſon of the year, being about the dog-days.

And as to that moſt obvious body, the air, or atmofphere, where-
in we live and breathe, tho' ſeveral opinions and arguments are found-
ed upon what authors call its natural and preter-natural, or violent ſtate,
yet he who conſiders, will find it no eaſie thing to determine what
ſtate of the air ought to be reputed its truly natural ſtate, unleſs in
my ſenſe of that expreſſion. I will not inſiſt on the heat and coldneſs of
the air; for, thoſe being manifeſtly very different in the depth of win-
ter, and in the heat of ſummer, and in differing regions of the air, as
at the top and bottom of high mountains, at the ſame time, and con-
ſtantly

*Whether the
atmoſphere be
in a natural
or a violent
State.*

PHYSICS.



stantly in different regions of the earth, as in *Barbary* and *Greenland*; 'twill not be so easie to determine what is its natural state: but that only which I shall now consider, is its state or tone in respect of rarity and density. For, since the air is supposed to be condensed by cold, and expanded by heat, I demand, at what time of the year, and in what countrey, the air shall be reputed to be in its natural state? If you name any one time, as the winter, or the summer, I ask, why that must be the standard of the tone of the air, rather than another season, or at least exclusive of all others? The like difficulty will also arise about the climate or the place. And these scruples are the more allowable, because learned men have deliver'd, that in some countries the mercury in the *Torricellian* experiment, is kept higher than in others, (as in *Sweden* than in *Italy*;) and our barometers inform us, that often, in the same place and day, the quick-silver in the same instrument considerably varies its height; which shews, that the air or atmosphere must necessarily vary its weight, and therefore probably its degree of rarity or density.

But I have a further consideration to propose in this affair: for, what if it shall appear, that neither in winter nor in summer, in *Sweden* or in *Italy*, or in whatever country, region, or season you please, the air we breathe is in any other than a preter-natural state; nay, that even when we have vehemently agitated and expanded it, by an intense fire, it is not yet violently rarified, but violently crowded; unless, in the sense above-mention'd, we understand the preter-natural state of rarification in the air, with respect to the tone it had before the last notable change was produc'd in it? This will, I question not, seem a surprizing paradox: but yet, to make it probable, we need only reflect upon two or three air-pump experiments; whereby it appears, first, that the air being a body abounding with springy particles, not destitute of gravity, the inferior must be compress'd by the weight of all the incumbent: and next, that this compression is so great, that tho' by the heat of the fire we could not bring a portion of included air to be expanded to above fourscore times its former dimensions; yet, without heat, by barely taking off the pressure of the superior air, by the help of our pneumatical engine, it was rarified more than twice as much: and I have, more than once, rarified it into above five hundred times its usual space; so that if, according to what is generally allow'd and taught, a body be then in a preter-natural state, when by an external force it is kept in a condition from which it incessantly tends to get free; and if it be then most near its natural state, when it has the most prosperously endeavoured to free it self from external force, and comply with its never-ceasing tendency; if this be so, I say, then the air we live in is constantly in a preter-natural state of compression by external force. And when it is most of all rarified by the fire, or by our engine, its springs having far more conveniency than before to display themselves,

selves, which they continually tend to do, it answerably approaches to its natural state, which is to be yet less compressed, or not at all. And I have carefully try'd, for many months together, that, when the air has been rarified much more than even a vehement heat will bring it to be, yet, if it were fenc'd from the pressure of the external air, it would not shrink to its former dimensions; as if it had been put into a violent state, from whence nature would reduce it; but it continued in that great and seemingly preter-natural degree of extension, as long as I had occasion to observe it. We might here shew, that this odd constitution of the air is so expedient, if not necessary for the motion, respiration, and other uses of animals, and, in particular, of men, that the providence and goodness of the wise author of the universe is thereby signally declared. But we are not here to employ final causes. From the whole we may learn two considerable things. And first, from what was said of the air, the natural state of a body may, sometimes, be allow'd to be not that which it really has a tendency to attain, but that whereto it is brought, and wherein it is kept by the action or resistance of neighbouring bodies, or by such a concurrence of agents and causes as will not suffer it to pass into another state. And secondly, we may hence learn, that, whatever be said of natures never missing her aim, and that nothing violent is durable; yet, bating an inconsiderable portion of aerial particles at the upper surface; for ought we know, the whole mass of the air we live in, and which surrounds the terra-queous globe, has been from the beginning, and will to the end of the world, be kept in a state of violent compression.



OBSERVATIONS

UPON THE

EFFECTS of LANGUID

A N D

UNREGARDED MOTIONS:

HOW superficially soever the local motion of bodies is treated of by the schools, who ascribe almost all strange things to substantial forms; we, who endeavour to resolve the phenomena of nature into matter, and motion, guided according to settled laws, must duly observe its operations. And tho' mathematicians and philosophers have, of late, applied themselves to consider the nature and laws of motion, yet the subject can never be too much cultivated, and some parts of it have scarce hitherto been touch'd upon.*

But,

* The laws of motion, and collision, both in elastic and unelastic bodies, in all kinds of mediums, and in all possible cases, are demonstrated by the geometricians of the last and the present age; as particularly by Dr. Wallis, Sir Chr. Wren, M. Huygens, M. Varignon, the Bernoulli's, Dr. Keil, and above all, by the great Sir Isaac Newton, whose three axioms, or grand laws of motion, for their extreme usefulness in philosophy, we shall here set down, as they are deliver'd by the incomparable author himself.

1. "All bodies will for ever remain in their state either of rest, or uniform rectilinear motion, unless compell'd to change either state by some force impress'd upon them.

"Projectils continue in their motions, bating for the resistance of the air, and the force of gravity, whereby they are

"impell'd downwards. A top, whose parts, their cohesion, by reason of constantly turning from a rectilinear motion, wou'd spin till it is stop'd by the resistance of the air; but the vast bodies of the planets and comets longer preserve their progressive circular motions, in spaces where they find less resistance.

2. "Every change of motion must be proportional to the moving force impress'd; and happen in the same strait line wherein that force is directed.

"If a certain force produces a certain motion; twice that force will produce double that motion; and thrice that force treble that motion; whether it be impress'd all at once, or by successive degrees. And this motion, having always the same direction with the power that causes it, must, if the body were before moving the same way there- with,

But, before I enter upon particulars, I must premise in general, that PHYSICS.
we are not to look upon the bodies, wherewith we are concern'd, as so many lumps of matter, which differ only in bulk and shape, or that act upon one another merely by their own distinct and particular powers; but as having peculiar and different internal textures, as well as external figures; on account of which, many of them must be considered as engines, so framed, and placed among other bodies, that sometimes agents, of themselves invalid, may have notable operations upon them; because a great part of the effect is due to the action of one part of the body it self upon another.† And there are, perhaps, more accounts, than we have yet thought of, upon which local motion may perform considerable things; and therefore I would not be understood to exclude the rest, tho' I shou'd hereafter take notice but of a few of these accounts. Now amongst the several things, upon account whereof we usually overlook, or under-

" with, be added to the motion of that
" body; if a contrary way, be subtracted
" from it; if impress'd obliquely, it must
" be added obliquely; and so be com-
" pounded with it, according to the di-
" rection of both motions.

3. " Re-action is ever contrary to and
" equal with action; or in other words,
" the actions of two bodies upon one ano-
" ther are always equal, but in contrary
" directions.

" Whatever presses or draws a body, is
" it self equally pressed or drawn by that
" body. Upon pressing a stone with the
" finger, the finger is press'd by the stone.
" When a horse draws a stone by means
" of a cord fasten'd thereto; the horse, if
" I may use the expression, is equally
" drawn back to the stone; for the cord
" being equally stretch'd, both ways,
" will by the same endeavour to relax it
" self, force as well the horse towards the
" stone, as the stone towards the horse;
" and hinder the one from advancing for-
" wards, as much as it retards the other.
" If one body strikes against another, and
" by its force changes, in any manner,
" the motion of that other, the first body
" will, likewise, suffer the same change
" of motion, but in a direction contrary
" to the force of the latter; because the
" pressure in this case is mutual. Now
" in such actions as these, there happens
" an equal change, not of the velocities,

" but of the motions of the bodies con-
" cern'd; I mean, if those bodies are not
" otherwise hinder'd. For the changes of
" velocities, which, in like manner, hap-
" pen in contrary directions, must, since
" the motions are equally changed, be
" reciprocally proportional to the bodies.
" And this law holds good in attracti-
" on."

Many excellent corollaries flow from these laws. As a specimen, take the following, which is demonstrated from them by the author himself, and made great use of in his philosophy.

" A body, moving with a compound
" force, will describe the diagonal of a
" parallelogram, in the same time that it
" wou'd the sides thereof, if that force
" were divided." From hence the effects
of all the mechanical powers are easily demonstrated; hence all compound motions are resolvable into simple ones; and hence Sir *Isaac* has proved, that the planets move in fix'd plains, and describe areas about the sun, proportional to the times.
See *Newton. Princip. p. 12, 13, 34, 375.*

† *M. Homberg* tells us, that the simple motion of a mill turn'd a bottle of wine, which was fix'd to it, into excellent vinegar, in three days time; and that, by the same means, he had from a pound of quick-silver, in three months time, four or five ounces of a blackish powder. *Hist. de l'Acad. A. 1700. p. 14.*

value

PHYSICS. value the efficacy of local motions, the chief are referable to the following observations.

The great efficacy of celerity.

1. *We are seldom aware of the great efficacy of celerity, in small bodies, and especially if they move but thro' a small space.** What rapid motion can do, may be judged by the powerful effects of bullets, shot out of our common canons, in comparison of the vast and unwieldy battering-rams of the ancients. Other examples of a like nature might be alledged; but the latter part of the proposition is what I am most concern'd to prove.

Having sometimes caused an oblong piece of iron or steel, to be turned, and placing my naked hand, at a convenient distance, to receive the little fragments, as they flew off from the rod; they were so intensely heated, by the quick action of the tool upon them, that they seemed almost like so many sparks of fire. And an expert workman in brass assured me, that the heat in the little fragments thrown off, when he turn'd that metal, was sometimes very offensive to his eyes; and that, when he employed a rough tool, which took off greater chips, he had found the heat so vehement, as not only to scorch his eye-lids, but the hard skin of his hands; for proof whereof, he shewed me a little blister, which had been so raised. And I learn'd from a famous artist, employed about the finishing of cast ordnance, that when with a strong, peculiar engine, he and his associates turned great guns, to bring the surface to a smoothness, the tools would sometimes throw off bits of metal, so heated, as to burn the fingers of those who ventured to touch them. An experienced artificer, also, assured me, that in turning brass, the little fragments acquire an intenser heat, than those of iron. And causing an artificer very briskly to turn a piece of ordinary wood, whilst I held my hand not far from it, the chips which flew off, struck it in many places, with that briskness, that 'twas with pain I endured the heat, they produced. It is farther considerable to our present purpose, that by an almost momentary percussive, with no great force, the parts even of a vegetable, may not only be intensely heated, but brought to actual fire; as we have tried by striking a good cane with a steel, or the back of a knife; for upon this collision, it would yield sparks, like a flint. So, likewise, by scraping good loaf-sugar with a knife, numerous sparks will be produced; but upon the collision of a flint and steel, not only fire, but even, vitrification, which the chymists esteem to the ultimate action of fire, is instantaneously produced; for the sparks which here fly off, are usually real and permanent parcels of stone, vitrified by the vehemence of the motion. And that this vitrification may be of the stone it self, tho'

* 'Tis an axiom, or acknowledged law of motion, that any body, how small soever, will move the largest, by impinging with the least assignable velocity, upon it; for, as we just now saw, action and reaction are equal.

steel is a metal of a far more fusible nature, I am induced to think, PHYSICS.
because flints will, by collision, strike fire with one another: the like
also may be done with rock-crystal, and even with diamonds, on
the mill whereby they are cut; tho' fire is not allowed to fuse
them.

Nor are fluid bodies, tho' but of small dimensions, to be excluded
from the power of making considerable impressions on solids; if their
celerity be great. Whether the sun-beams consist of very minute cor-
puscles, which continually issuing out of the sun's body, swiftly impel
one another forwards in strait lines; or whether those beams are made
by the brisk action of the luminary upon the contiguous fluid, and pro-
pagated every way in strait lines, thro' some ethereal matter harboured
in the pores of the air; it will be agreeable to either hypothesis,
that being refracted or reflected, by a burning-glass, to a focus, they
by their concurrence, compose a small portion of fluid matter, so vio-
lently agitated, as to kindle green wood in less than a minute, and
to melt not only tin and lead, thinly beaten, but leaf-silver and
gold. *

The operation of small portions of fluid matter on solid bo-
dies will be exemplified hereafter; I shall here only, in general,
point at the great and surprizing effects of lightning. The last in-
stance of its power within my acquaintance was, the melting of a me-
tal by the flame, in its passage, which probably lasted but the twink-
ling of an eye. And that even a small parcel of air may communicate
a considerable motion to a solid body, is confirmed by the violent
force of a bullet shot out of a good wind-gun; which I found by
trial, would be flatted, almost into the figure of an hemisphere, by
being thus thrown against a metalline plate. And farther, to
shew what a vehement agitation may be communicated to the parts
of a solid body, by celerity; going to take up this bullet, I found it
too hot to be, without pain, held betwixt my fingers.

2. *We are too apt to think that fluid bodies, because of their softness, cannot, by their bare motion, especially if insensible, have any sensible effect upon solids; though the fluid moves and acts as an entire body.* *The force of fluids upon solids.* It is not
my design here to insist on the efficacy of such fluids, as may
have their motions discovered by the eye, as flowing water; or per-
ceived by the touch, as winds; but of such only, as we do not im-
mediately see or feel.

* M. *Villette* lately exhibited a burning
concave forty-seven inches wide, and
ground to a sphere of such a radius,
that its focus was about thirty-eight
inches from the vertex of the glass. The
metal of it was a mixture of copper,
tin and tin-glass. This concave melted
iron-ore in 24", began to calcine talc in

40", and as M. *Villette* said, wou'd calcine
asbestos. It melted a six-pence in 7"¹/₂
and a half-penny in 16". It turn'd an eme-
rald into a substance like a turquoise-
stone; and diminish'd a diamond, that
weigh'd four grains, ²/₈ of its weight. See
Philos. Transf. N^o. 360. p. 976.

PHYSICS.

It has been frequently observed, that, upon the discharge of ordnance, not only the sound may be distinctly heard at a great distance; but that the tremulous motion of the air, which produces sound, has been able to shake, and sometimes to break glass-windows afar off; especially, when they stand in the way, wherein the propagation of the sound is directly made. And tho', in some instances, it may be urged, that such effects are produced from the motion of the earth, immediately shook in the explosion; yet I see no necessity here, of having recourse to any thing, but the undulating motion of the air; since the like may be produced by motion continued thro' fluids. *Borelli*, discoursing of the force of percussion, has this remarkable passage.

"I was," says he, "at *Tauromenium* in *Sicily*, when the mountain *Ætna* broke out near *Enna*, a town distant about thirty miles from *Tauromenium*; whilst the chasm sent out, now and then, with great noise, fire and flame; all the houses were sensibly shaken: and it was observed, that such as looked directly towards the chasm, were most agitated; those looking otherwise, shaking more slowly. Upon which fact, he thus argues. "Had this trembling been occasioned by the shaking of the ground of *Tauromenium*, all the houses would have been equally shaken; since this inequality of motion could not be ascribed to their different situation. Hence, then, we must needs conclude, that the agitation was produced, by the impression of the air upon the walls of the houses; which demonstrates the great efficacy of a sound, tho' at thirty miles distance."

I was once invited by an engineer, to see trial made of an instrument, which he had contrived suddenly to sink a ship; but in the experiment, which was successfully made upon an old frigate, the explosion was so great, that it raised a kind of storm in the water round about, and shook some vessels, that lay at a distance, so as to make those who stood upon the decks to stagger. And in the late sea-fight between the *English* and *Dutch*, tho' the engagement happen'd very many leagues from the *Hague*; yet the report of the guns not only reached to that place, but had so considerable an effect there, as to shake the very windows. And if there be a greater disposition in some other bodies, than there is in glass-windows, to receive impulses from the air, they may be sensibly wrought upon by the noise of a single piece of ordnance; as appears by a remarkable circumstance mentioned by *Simon Pauli*; in his treatise of malignant fevers. He says, that a *Frenchman* having his arm mortified, they were obliged to take it off; after which operation he lived eight days, very strongly convulsed; that standing with others by his bed-side, once when the great guns, whereof they took no notice, were fired from the king's ships; as every one went off, he clap'd his left-hand to his stump, and lamentably complain'd of pain there; so insufferable was each single explosion to him; tho' the guns were at a great distance, and fired not upon or near the land, but from the sea. And the commander of a man of war assured

The Effects of languid Motion consider'd.

475

PHYSICS:

fired me, that some men on board him, whose bones were broken, would sadly complain of the torment they suffered by the shake of the enemies cannon; tho' they were too much accustomed to the report of great guns, to be offended by the bare noise. But if any one shou'd here suggest, that the water hath a share in this communication; yet there is one kind of sound, that must be confessed to be propagated by the air, as being made in it; and that is thunder, whose noise sometimes so vehemently affects it, tho' without producing any sensible wind, that I have observed it to shake large strong-built houses, notwithstanding the distance of the clouds, where the sounds were first produced. Some sea-captains too, who had sailed to the *Indies*, told me, they have had their ships so shocked with the thunder, as to displace their great guns. And as the celerity, where-with sounds are propagated thro' the air, is exceeding great, this effect is the less surprizing. *Mersennus* observes, that a bullet, shot out of a cannon, moves two hundred and forty yards in a second; but I have more than once found, that sounds pass above four hundred yards in the same time, in *England*: tho' according to *Mersennus*, a sound moves, in that time, many yards more in *France*; which may possibly proceed from the different consistence of the air in those two places.*

The great loudness of these sounds, and the vehement percussion the air receives in their formation, may make it probable, that it was only the impetuosity of the motion of the medium, which gave the shake to the windows and other solid bodies, made to tremble by the report of cannon or thunder; whilst, perhaps, some of those tremulous motions of solid bodies, might either depend upon, or be promoted by, the peculiar disposition, that glass, and other bodies, endowed with elasticity, may have to be moved by certain appropriate sounds, more than they would be by others that were louder. If this be admitted, it will not render our instances improper to the present design; but only make some of them fit to be referred to another head. I shall, therefore, conclude this, with an odd observation of *Platerus*, which argues, that where there is a peculiar disposition, even in a firm body, it may receive considerable impressions from so languid a motion of the air, as is not sensible to other bodies of the same kind.

"A woman," says he, "taken ill of a suddain, continually complain'd, that she shou'd be suffocated, tho' no signs of it appeared. This complaint of hers was always the greatest, when any of the bystanders approached her, though ever so gently; for she said, that

* The reverend Mr. *Derham*, from a variety of accurate experiments, concludes that sounds, at a medium, move 1142 feet in a second; but that if the wind favours

them, 'tis possible they may reach 1200; or if it be directly contrary, only 1120 feet in that time. See *Philos. Transf.* N^o. 113. p. 2.

PHYSICS.

“She at those times felt a breath of air come upon her, as if she were instantly going to be choak’d. She hardly remain’d in this condition for two days, and then dyed.” Our author adds, “I have known other patients complain of the like breath of air, being ready to strangle them, when any one came nigh them; and always found it a very bad sign.”

What is wanting in the bulk of some bodies made up by their number.

3. *We undervalue the motions of bodies too small to be visible or sensible, notwithstanding their numbers, which enable them to act in swarms.* Most men think of the effluvia of bodies, and their motions, as of finer sorts of dust, blown against the surfaces of bodies, and stopped in their progress, without penetrating into the internal parts. And according to this notion, it is no wonder, they should have but faint operations upon them. But we shall judge otherwise, from considering, that these corpuscles are, by their minuteness and figure, enabled to pierce into the innermost recesses of the bodies they invade. For tho’ we suppose each single particle to be very minute; yet since we may imagine their numbers exceedingly great, it need not seem incredible, that they should have a considerable operation upon others at rest, or that have a motion too slow, to be sensible. If we turn up an ant-hill, we may sometimes see such an heap of eggs, as a few of those insects would not be able to draw after them; but if, in swarms, each lays hold of her own egg, it is surprizing to see, how quickly the whole heap will be removed. And in those cases, wherein the invading fluid does not quite disjoin, and carry off any great number of parts; its operation may be illustrated by that of the wind upon a tree in autumn, whilst it makes itself a multitude of winding passages; bending some of the twigs, breaking off part of the fruit, and leaves, and variously altering the situation of others. And suppose we cast two lumps, the one of sugar, the other of amber, into a glass of water; they will both presently fall to the bottom; and, tho’ perhaps, the amber may be lighter than the sugar, yet the aqueous particles are far from being able to displace the amber, or any sensible part of it, or to exercise any visible operation upon it; but the same minute particles of the liquor, being of a figure, which fits them, to insinuate, every way, into the pores of the sugar, tho’ the lump consisted of very numerous corpuscles; yet the multitude of the aqueous particles to which they are accessible, is soon able to disperse them all; and carrying them along with themselves, presently render the whole lump of sugar invisible.

If, also, by a due degree of fire, we abstract from running mercury four or five times its weight of good oil of vitriol, there will remain at the bottom, a dry and brittle substance exceeding white; and if upon this heap of mercurial and saline bodies, we pour a large quantity of water, and shake them together, the multitude of little white grains, which make up the mass, will be pervaded, and manifestly altered, by the dispersed corpuscles of the water. But to in-

stance.

stance in fluids; tho' it will easily be granted, that the flame of spirit of wine, is but a visible aggregate of such effluvia, swiftly agitated, as, without any sensible heat, would, of themselves, invisibly exhale; yet if we hold the blade of a knife, or a thin plate of copper, in the flame, we shall quickly discern, by the great heat acquired, what a number of corpuscles must have been agitated by the fiery particles; if we suppose, what is highly probable, that they materially penetrated into the innermost parts of the metal. But, whether we suppose this or no, it will appear, that so yielding a body, as the flame of spirit of wine, is able soon to act very powerfully upon the hardest metals. The like power may be farther estimated by the motions of animals; for tho' the animal spirits are minute enough to pass thro' nerves, whole channels cannot be discerned; yet they serve to move, in various manners, the limbs and unweildy bodies of the largest creatures. We might add, that in moist weather, the aqueous particles, swimming in the air, will enter, in such great numbers, into the pores of a thick rope, as to make it contract, tho' suspended with a great weight, tied at the end, to hinder it.

But as to the determination of the motion of fluids, I observe, that, tho' the wind, blown out at a small bent tube of glass, call'd a blow-pipe, seems not to have any great celerity, in comparison of the parts of flame; and is it self of little force; yet when the flame of a lamp or candle is directed by it, so as to beat upon a body, at a convenient distance, it may be made to melt silver, or even copper itself; which yet may be kept, for many hours, unmelted, in a red-hot crucible, or the flame of the lamp or candle, unassisted by the blast. And if we can so contrive it, that a flame does not only touch the surface, but intermingle with the smaller parts of a body, it will then have a far more powerful operation. For tho' a pound or two of tartar may require some hours to calcine it to whiteness, if the flame have immediate access, only to the outward parts; yet it will be calcined in a very small part of that time, if, mixing with its gross powder, an equal weight of good salt-petre, the mixture be fired, and kept stirring, that the parts of the kindled nitre, may have access, at once, to very many parts of the tartar. And by a little artifice, nitre it self may, without tartar, be speedily reduced to a calx, not unlike the former. The load-stone is acknowledged to act by the emission of insensible particles. For, tho' iron and steel be solid bodies, and magnetic effluvia corpuscles so very minute, as readily to get in at the pores even of glass itself; yet, entering the steel in swarms, they may operate so violently on it, as to attract above fifty times the weight of the magnet. For to these I rather ascribe magnetical attraction and suspension, than to the pressure of the ambient air; because I have found on trial, that such a pressure is not absolutely necessary to magnetical operations. And farther, as to the power of magnetical effluvia upon iron, I took filings of iron fresh made, that the

PHYSICS.

the virtue might not be diminished by rust, and having laid them in a little heap upon paper held level, I applied to the lower side of it, just beneath the heap, the pole of a vigorous load-stone, whose emissions diffusing themselves thro' the metal, manifestly alter'd their appearance, and produced many erect aggregates of filings, placed one above another, like little needles: and as these needles stood erected upon the flat paper, so they would run to and fro, according as the load-stone, which was held underneath, moved one way or the other; and as soon as that was taken away, all this little stand of pikes would fall again into a confused heap.

There are two principal ways of explaining the change of water into ice, either of which affords a notable instance to the present purpose. For the particles of water, and much more the corpuscles of cold, are confessed to be singly too small to be visible; and their motions are not said to be swift, but rather judged slow; yet these, by their number, produce so forcible a motion in glaciation, as to break bottles of glass, earth, or metal: and the expansive endeavour of freezing water, is not only able to do this, but to perform so much greater things, that my trials have made me sometimes doubt, whether any thing in nature, except kindled gun-powder, moves, bulk for bulk, more forcibly, tho' the motion seems to be very slow.

*The propaga-
ble nature of
motion.*

4. *We are not sufficiently aware of the propagable nature of local motion, thro' different mediums and solid bodies.* There are four principal occasions, on which, I have observed, men usually think the communication of motion much more difficult, than indeed it is.

There are many, who, observing how some bodies, which hit against such others as are hard, usually rebound, easily persuade themselves, that motion can scarce be transmitted thro' them: but tho' in many cases, the progressive motion be either inconsiderable, or not sensible, yet the impulse may make a considerable impression, and be communicated to a great share of the particles of that matter, whereof the solid consists; as we see in striking a timber tree at one end, the motion may become sensible at the other. And tho' bell-metal be a very hard body, yet its solidity hinders it not from being sensibly affected by a weak motion; as may be made appear, by gently passing a pin along a part of the edge of a bell, which communicates to the whole a vibrating motion, and causes sound, as will be audible for some time: such a stroke also upon it with the like small instrument, will have the same effect. Now, if sound consists in the undulating motion of the air, and so, in our case, requires a vibrating motion in the sonorous body to impart it, we must grant a wonderful propagation of it in solid bodies themselves; since the point of a pin gently striking a part of a very solid metal, no bigger than it self, cou'd thereby produce a sensible motion, and that several times circulated, to millions of parts equal to it in bulk, and much exceeding it in hardness. And what shews, that even soft and yielding bodies, faintly

faintly moved, have a power of putting such hard ones into motion, I found almost the like effects by passing the pulp of my finger, a little way, along the lower part of a bell. As to the propagation of motion in solid bodies by heat, it greatly depends upon the particular textures of the bodies. For heating a piece of glais, or a fire-stone, I could, without any inconvenience, hold my naked hand upon parts very near those that were fired: but if one end of a rod of iron be made red-hot, the heat of that end will be so propagated towards the other, as to offend the hand at several times the distance.

'Tis observable in many buildings, that a stamp of the foot, or bare treading in one room, will have a sensible effect in most of the others: and it often happens, that by the hasty shutting of a door, the whole house is made to tremble; whence we may argue, that, even amongst solid bodies, motion made in one place may be readily propagated to many others. And if the sudden impulse, and compression of the air, made by a door, supposed to be hastily shut, hath any considerable share in the effect, this phenomenon will serve to shew the efficacy, even of such a motion of a fluid body, as we cannot directly feel, upon several large ones, that are firmly connected. In earth-quakes, which are supposed to proceed from the explosion of subterraneous exhalations, the tremulous motion sometimes extends very far beyond the places, where the explosions were made. And, tho' *Seneca* confines the extent of earth-quakes to two hundred miles, yet later observations shew them to reach much farther. *Josephus Acofta* affirms, that in the kingdom of *Peru*, in the year 1586, an earth-quake spread along the shore of the pacific sea 160 leagues; and adds, that sometimes it has in those parts run on from south to north 300 leagues. And in the year 1601, eminent writers relate a much larger earth-quake to have happened, reaching from *Asia*, to the *French* coast; and, besides some *Asiatic* regions, it shook *Hungary*, *Germany*, *Italy*, and *France*, that is, a great part of *Europe*. And if it be true, that it lasted not much above a quarter of an hour, 'tis the more likely, that this earth-quake shook great tracts of land beyond those places, to which the fired matter, passing from one cavity to another, could reach in so short a time; for in trains of gun-powder, the fire does not run on near so swiftly as one would imagine. I my self, also, have seen and felt the effects of a small, harmless earth-quake, near *Oxford*, which extended many miles in length.

But it appears to how great an extent a motion, excited in a very narrow compass, may be propagated thro' different mediums, by the relation of *Famianus Strada*, who giving an account of a work, contrived to keep the city of *Antwerp* from being reliev'd in a siege, by the river *Scheldt*, tells us the effects of a floating mine, contrived to destroy it, in these words. "On a sudden, the fatal ship burst, with such an horrid crash, as if the very sky had rent asunder, heaven
" and

PHYSICS.

“ and earth had charged one another, and the whole machine of the globe had trembled. For the storm of stones, chains and bullets, being cast out with thunder and lightning, there followed such a slaughter, as no man could have conceiv'd. The castle on which the infernal ship fell, the pile work of the bridge to St. Mary's fort, that part of the naval bridge next the castle, soldiers, mariners, commanders, canons, armour, and arms, all swept away by this furious whirl-wind, tossed into the air, and dispersed as wind scatters the leaves of trees. The *Scheldt*, prodigiously gaping, was first seen to discover its bottom, then swelling over its banks, rose above the ramparts; and huge stones, thrown out to above a miles distance, were there found struck deep into the ground: the motion of the panting earth extending its force above nine miles.” Which if he means the miles of that country, or *Dutch* leagues, are 36 *English* miles.

But even the motion of a coach or a cart, will, at a considerable distance, make the buildings considerably shake: 'tis, therefore, the less surprizing, that in a calm night, the march of a troop of horse may be felt, by attentive scouts, at a great distance, by the shake of the ground; tho' perhaps the impulse of the air, conveyed along the resisting surface of the earth, may principally contribute to the effect.

And let it be here observed, that in peculiarly disposed bodies, and especially, in organical ones, a very languid motion may have a far greater effect, than it could produce by a bare propagation of it self. For it may so determine the motion of the spirits in the body it works upon, as to make multitudes of them act, as if they conspired to perform the same motions: as when a ticklish person, by having the pulp of one's finger passed gently along the sole of his foot, or the palm of his hand, has various muscles, and other parts of his body and face put into preter-natural or unusual motions. And most men, by being lightly tickled with the end of a feather, or a straw, within their nostrils, have their heads and many parts of their bodies put into that violent commotion, wherein sneezing consists. And I remember, that having been, by a distemper, for some time deprived of the use of my hands; it more than once happened to me, that sitting alone in a coach, if the wind chanced to blow a single hair upon my face, the tickling it produced was so uneasy, as to make me apprehend falling into convulsions, or a swoon, before I cou'd get it removed by my servant.

There are others who cannot believe, that local motion, especially if it be languid, shou'd be propagated thro' differing mediums, each of which, except that wherein the motion is begun, must, they think, either repel, or check and deaden it. To these I recommend the experiment of a watch heard to strike, when inclosed in an exhausted receiver. I have also perceived my own to strike in my pocket, and felt the motion of the balance at the same time. But that motion

The Effects of languid Motion consider'd.

481

PHYSICS.

tion may be propagated thro' different mediums, seems the more probable, by the shakings, often felt on beds, standing in rooms close shut, when loud claps of thunder are produced in the clouds.

Agricola tells us, "that if an animal be thrown into a cave at *Viburg* in *Carelia*, a country of *Scandia*, 'tis said, an intolerable sound breaks out from it, with a gust of wind; and that if any small weight be cast into a cave there is in *Dalmatia*, tho', according to *Pliny*, it be done on a calm day, yet a storm, like a whirlwind, is immediately raised thereby."

As some are unwilling to allow that motion can be considerably propagated thro' solid bodies; so, on the contrary, there are others, indisposed to think, that it is near so propagable, as indeed it is, thro' fluid bodies; because they presume, that the parts of fluids easily giving way, will deaden the impulse received by such of them, as are first acted upon by the impelling body. And, there is yet another sort of men, who cannot believe, that it should be, thro' such a medium, propagated to any considerable distance. But if luminous bodies act on our eyes, not by a substantial diffusion of extremely minute particles, as the *Atomists* would have it, but by a propagated impulse of some subtile matter, contiguous to the shining body, as the *Cartesians* maintain; it will be manifest, that a body exceeding small may give a brisk motion to a portion of fluid matter, many millions of times bigger than it self; since in a dark night, a single spark of fire may be seen in different places, whose distance from it many thousand times exceeds the diameter of the spark: not to mention the great distance, at which the flame of a small taper may not only be seen, but appear larger, than near at hand. And if we compare the diameter of the planet *Venus*, which yet shines but with reflected light, with her distance from the earth, we may easily conclude, that the fixed stars, probably so many suns, which shine by their own native light, must impel a stupendous proportion of ethereal matter, to be able, at that immense distance, to make such vivid impressions, as they do, upon our eyes. And tho' fluid bodies do easily yield to solids, and thereby quickly deaden the motion of them; yet the motion being lost, only in regard of the solid body, is not lost, but transmitted, and diffused in respect of the fluid. Thus when a log of wood, or any such body, specifically lighter than water, is let fall into the middle of a pond, tho' its progress downwards be checked, and it is brought to rest quietly on the surface of the water; yet its motion is not lost, but communicated to the parts of the water, against which it first strikes, and by those to others, till at length the waves, produced on the surface, spread themselves to the brinks, and would, perhaps, be farther expanded, if these did not hinder their progress. Whence we may learn, that, tho' the nature of fluid bodies requires, that their parts be actually distinct, and separately moved; yet the particular corpuscles, which compose them, being

PHYSICS. touched by several others; the new motion, produced in some of them, by an impelling solid, must needs make them impel the contiguous corpuscles, and these, such as lye next to them; and so the impulse may be propagated to a vast distance: since, in a fluid body, the corpuscles yield more easily to the impelling power; and being here almost balanced by others of the same fluid, a very small force may suffice to impel them. Thus, tho' the brass scale of a balance, several inches in diameter, may be supposed to outweigh many myriads of such particles as compose water, wine, &c. yet, such a scale being duly counter-poised with another, I have easily put it into various motions, only with the invisible effluvia of a small piece of amber. And if we consider the instance of the concentric circles, made by the falling of a stone into stagnant water, we shall be the more easily persuaded, that even in an heavy fluid, a motion may reach much farther, than men are usually aware of, beyond the parts on which it was first impressed. An experienced navigator, who much frequents the coast of *Greenland*, and other northern regions, to fish for whales, assured me, he had not only often heard the ice, in breaking, make a more terrible noise, than the loudest claps of thunder with us; but that, sometimes, when the sea-water had undermined the foundation of mountainous pieces thereof, he hath known it suddenly fall into the sea below, with such violence, as to make a storm, at a great distance off; and that, once, when he lay two leagues from the place where a stupendous mass of ice fell, it raised the waves so high, as to wash over the stern of his ship, with great danger to some of the men; and to sink several of his shallops, that were riding near; tho' scarce any vessels in the world were so fitted for rough seas as those. The air, indeed, is a much thinner fluid than water, yet because we are apt to think it indisposed to propagate motion far off, I must observe, that we are not to judge of it, by the effect it has on our ears, when the sound is made in disadvantageous places. For one, who hears a violin plaid on in an hung room, will think the sound faint in comparison of what it would appear, if the same instrument were touched in an arched roof without hangings; soft and yielding bodies being apt to deaden the sound, which the figure and hardness of the vaulted chamber would reflect. So, when a man speaks in the free air, we usually take no notice of the motion of the air, beyond the place we are in; but if the place happens to have an echo, tho' at many times that distance from the speaker, we may then easily take notice, that the motion of the air was carried on, and that with vigour, much farther than we should otherwise have observed. And I have often thought, that, even by the better sort of echoing places, we are not informed, to how great a sphere the motion, which the air is put into by sounds, may extend, where its diffusion and force are neither hindered nor weakened by bodies, placed too near, or indisposed to promote its operation. *Fromundus*, who being professor of philosophy at *Louvain*, in the year

The Effects of languid Motion consider'd.

483

PHYSICS.

1627, might easily know the truth of what he relates, affirms, that at the famous siege of *Ostend* in *Flanders*, the thunder of the great ordnance was heard above thirty *Dutch* leagues, or one hundred and twenty *English* miles. And that is yet more strange, which he adds concerning the diffusion of the sound of a drum, which was perceived at sea, twelve leagues off. To which may be added, concerning echoes, the notable relation in *Varenius*, of an observation made by *David Fralichius*, who, in the company of two students, had the curiosity to visit the mountain *Carpathus*, esteemed the highest of all in *Hungary*, and said to be much more steep, and difficult of access, than any of the *Alps*. This *Fralichius*, having related, with what difficulty he and his companions ascended above that region of the air, where they met with clouds, and vehement winds, adds; "At this height I fired a gun, which at first gave a report no louder than if I had broke a stick; but some time after, we heard a long continued murmur, which fill'd all the lower parts of the mountain, valleys, and woods. And descending along the snow, which had long lain between the valleys, we again unloaded our gun, which made a more dreadful noise than that of the largest canon; so that I fear'd the whole mountain was going to tumble: and this sound continued for half a quarter of an hour, till it had enter'd the innermost caverns, whence, the parts of the air crowding each other, it was beat back; but for want of such cavities at the top of the hill, the sound was at first insensibly reverberated, till coming lower and nearer to the caves and valleys, it was more forcibly dash'd against them."

5. *We seldom regard what the modification of the invisible motion of fluids may perform, on the disposed bodies of animals.*

The effects of the invisible motion of fluids upon animal bodies.

There is a peculiar aptitude required in those animals, or some particular parts of them, which are to be sensibly affected by such motions as we here mean; which would, otherwise, be too languid to produce any great effect.

It seems the less strange, that continuing sounds, and durable impulses of the air, or other fluids, should have a manifest operation on solid bodies, considering the multitude of strokes, which may, in a very short time, be given, by the parts of the fluid to the consistent body. For tho' each of these, apart, would, perhaps, be too languid to have any sensible effect; yet frequent repetitions, by the successive parts of the fluid, have a very great power: as may be argued from the swing given to pendulums by a very languid force; as also from the tremulous motion, imparted to the metalline spring of a musical instrument, by the correspondent one given to the air by another string. *Scaliger* tells a pleasant story of a *Gascon* knight, whom the sound of a bag-pipe would presently force to make water: and I know a very ingenious gentleman, upon whom the running of a tap has almost the like operation. The noise of an ungreased cart-wheel, the scraping of a knife, and some other such acute sounds, so affect several

The Effects of languid Motion consider'd.

ral parts of the head, as to set the teeth on edge. But these effects are much less considerable, than that producible on an ingenious domestic of mine, whose gums will bleed upon the noise of tearing brown paper. Sir *Henry Blunt*, in his voyage to the *Levant*, tells us, that he saw in *Grand Cairo*, a nest of four-legged serpents, two feet long, black, and ugly, kept by a *Frenchman*, who, when he came to handle them, would run, and hide themselves in a hole; but upon the music of his cittern, would all crawl out again, and climb up to him, till he gave over playing, when they ran away again. And a person of great judgment and integrity told me, that he, with many *European* merchants, had seen, in the *East-Indies*, the owner of some large tame serpents, taken by the common people there for a *Magician*, who by music could make them dance in strange frightful and very erect postures; or seem to sleep, and, as it were, melt away with pleasure, by particular parts of a tune. And according to *Kircher*, there is a great fish, in the *Streights*, between *Sicily* and *Italy*, much affected with a peculiar kind of tune, whereby mariners allure it to follow their vessels. I will not affirm, there is any certainty in the famous tradition, of the lion's being terrified at the crowing of a cock; for a late *French* traveller affirming, that rowing along the brink of *Euphrates*, they were, for many hours in the night, terrified by lions that attended them, and were not at all afraid of the frequent crowing of the cocks, which chanced to be in the passage-boat. I might add, that many sleeping persons will be more easily awaked, being called upon by their own names, than by others, tho' uttered with a louder voice. I shall not insist on that example of the operation of a sound, afforded by the starting of men, or larger animals, upon a surprising noise; whereby the whole bulk of the animal is suddenly raised from the ground, which, perhaps, could not be done by the bare counter-poise of some hundreds of pounds; because this seems to depend rather upon the loudness or acuteness of the sound, than any determinate modification of it. But the most eminent instance of the efficacy of peculiarly modified sounds upon disposed bodies, is afforded us by what happens to those who are bit by a *Tarantula*. For, tho' such persons will calmly hear several other tunes, yet when a peculiar one comes to be plaid, it will set them a dancing with a surprising vigour; and this dancing will sometimes continue for many hours, if the music ceases not. I know there are some, who question the truth of the things related of these *Tarantati*; and I grant, that some fictions may have passed under the countenance of so strange a truth. But, besides the affirmations of learned men, I have received attestations hereof from an acquaintance, who, at *Tarentum* it self, whence the insect takes its name, saw many bitten persons in their dances; and amongst the rest, a physician, on whom the tune, that fitted his distemper, had the same operation, as on the other patients. And *Epiphanius Ferdinandus*, who practised physic in *Apulia*, and

Calabria,

Calabria, for many years, not only delivers, upon his own personal observation, several narratives of the effects of music upon the *Tarantati*, but invites any, who may doubt of the truth of such narratives, to repair to him, at a fit season; undertaking to convince them by ocular demonstration. I have, also, my self seen an ingenious person, who in *Calabria* or *Apulia*, was himself bitten by one of these venomous insects; tho' the hurt was slight. Yet this, together with what he had seen in others more unhappily bitten, confirm'd what sober writers affirm of the symptoms and cure of that poison. A very honest, and sober musician, hath, several times, affirmed to me, that he could, at pleasure, by playing a certain tune, which wou'd not affect others, make a certain person weep, against her will. I might add, that when I have been taking physic, or am any thing feverish, the repetition of two verses of *Lucan* seldom fails, as I have tried, of producing in me a chillness, almost like that, but fainter, which begins the fit of an ague: tho' I look not on this as a strong proof of the physical efficacy of sounds; because those two verses having been emphatically read, when, several years ago, I lay sick of a slow fever, and could not rest, they made so strong an impression on me, that whenever I am under a discomposure, like what then troubled me, those verses revive, as it were, that indisposition in me.

'Tis the less strange, that the vibrating motion of the air, which produces sounds, should produce such effects upon disposed organical bodies; since light itself may have a notable operation, after the same manner. For the sun-beams, by beating upon the eyes or faces of some, who come suddenly out of a shady place, presently make them sneeze; which is not done without a vehement motion of several parts of the body. And tho' colour be but a modification of light; yet it was anciently a practice, to present red objects to elephants, to make them more fierce. It is a familiar observation, that red clothes irritate turkey-cocks: and *Valesius*, a learn'd physician, tells us of a person, who, if he looked upon red objects, would not only have his eyes offended, but was also thereby subject to an effusion of humours in the neighbouring parts.

6. We seldom suspect, what efficacy the invisible motions of fluids may have on inorganical bodies, upon account of some determinate agreement, or relation betwixt a peculiar texture of the one, and the peculiar modification of the other's motion. To manifest this by particular experiments, I shall begin with that common one, made with two unison-strings of a musical instrument; wherein a motion of the one, will suffice to produce a visible motion in the other. But that the shake of the untouched string, may not be suspected to be communicated to it, by the propagated motion of the instrument; I shall add, that a wire may, without another string, be brought to tremble, by a determinate sound, made at a distance, which produced but such an impulse of air, as could neither be seen, or felt by a by-stander; nor would communicate

The efficacy of unregarded motions in fluids, upon inorganical bodies.

PHYSICS.

cate any sensible motion to neighbouring strings. It is true, that, in this case, the string, in which the trembling was produced, being a single, long, slender, and springy body, fastened at both ends to a stable one; it may seem unreasonable to expect, that any thing like such an effect should be produced by the same cause, in bodies which do not appear so qualified. But as a certain degree of tension, is the principal qualification in order to this phenomenon, without which, all the others would be unavailable; perhaps in bodies, of a very different appearance from strings, the various textures, connexions, and complications, that nature, or art, or both, may make of the parts, will bring them to a state equivalent to the tension of the strings of musical instruments; whereby several of the mentioned parts will be stretched in the manner requisite, to receive a vibrating motion from some peculiar sounds: and, possibly, these trembling parts may be numerous enough to affect their neighbours, and make in the body they belong to, a sensible tremulous motion. I found upon trial, that if a large, hemispherical glass were conveniently placed; a determinate sound, made at a convenient distance from the concave surface of the glass, would make it sensibly ring, as a bell, soon after it has been struck. But this noise was the effect of a determinate sound; for tho' the voice were raised to a higher tone, or if the sound were made louder, the same effect would not ensue. And I have been assured, that one *Petterus*, a vintner at *Amsterdam*, could take the tone of a rummer-glass, and raising his voice into that tone, first make it tremble, and then burst. I observed also, that large empty drinking-glasses of fine white metal, had, each of them, its determinate tension. For causing the strings of a musical instrument to be variously screwed up, let down, and briskly struck, we found, that the motion of one string, when stretched to a certain tone, would make one of the glasses ring, and not the other; nor would the sound of the same string, tuned to another note, sensibly affect the first glass, tho' perhaps it might have its operation upon another. We must not omit, that after we had found the tone proper to one of the glasses, having broken off part of the foot, the same sound of the string would no longer be answered by the vessel; but we were obliged to alter the tension of the string, to produce the former effect. A famous organist has assured me, that at particular stops of the organ, some seats in the church would tremble; tho' by his relation, I suspected this to be effected chiefly by the greatness of the sound: but I have several times since observed certain sounds of an excellent organ to make, not only my seat in the church to tremble under me, but to produce an odd motion in the upper part of my hat, which I could plainly feel with my hands. And, what inclines me to believe that this effect depends upon the determinate tone, rather than upon the loudness of the sound, is, that I have often felt such a kind of motion in the upper part of my hat, upon pronouncing

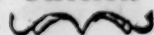
pronouncing some words in ordinary discourse. Nor is it only in such small, and yielding bodies, as hats, and strings, that sounds, not boisterous, may produce sensible effects; for if they be adapted to the texture of the body, to be work'd upon, they may excite motions in it, tho' it be either solid, or very bulky. An ancient musician affirmed to me, that playing on a bass-viol, in the chamber of one of his scholars, when he came to strike a certain note upon a particular string, he heard an odd kind of jarring noise, which he thought, at first, had been either casual, or proceeded from some fault in the string; but having afterwards frequent occasion to play in the same room, he plainly found, that the noise was made by the tremulous motion of the casement of a window, which would be made to tremble by a determinate sound of a particular string, and not by other notes, either higher or lower. To this instance, I shall add a second, that, I confess, I was not forward to believe, till trial had convinced me of its truth; to which end, I took the musician, who told me the story, with me to the place he mention'd; which was an arch, and would not answer to all notes indifferently, when we stood in a certain part, but to a determinate note, which he told me was *ce fa ut*, a little flatted; to which it answered very well, and not sensibly to others: and even when I made him raise his voice to an eighth, as consonant as those two sounds usually are in all other cases, the vaulted arch did not appear to us affected with it. He informed me too, that he had tryed in most arches about the city, and could find no such peculiarity in them, as being resonant to all notes and sounds indifferently, that were strong enough; and farther, that, as this arch, for a hundred years, has been observed to have this property, so an ancient and experienced builder informed him, that any vault, which was exquisitely built, would peculiarly answer to some determinate note or other.

7. *We look upon several bodies, as having their parts in a state of absolute rest, when indeed they are in a forced state, as of tension, compression, &c.* This observation will, probably, seem paradoxical. For when an intire body of a solid consistence, and uniform matter, appears to be moveless, we take it for granted, that its parts also are perfectly at rest: yet some obvious phenomena will teach us, that its component corpuscles may have various motions, and endeavours among themselves. Thus when a bar of iron, having been well hammered, is newly taken off from the anvil; tho' the eye can discern no motion in it, yet the touch will readily perceive it to be very hot: and the brisk agitation of its insensible parts will become visible, by pouring a liquor upon it. When the lath of a cross-bow stands bent, tho' neither the eye, nor touch, perceive any motion in the springy parts, yet if the string be cut, the sudden motion, tending to restore it to the figure, it had before, discovers an elasticity, whence we conclude it was in a state of compression. And tho' the string of a bent bow, likewise,

*Various bodies
not at rest, but
in a state of
tension, &c.*

PHYSICS.

likewise, appears to be in a state of rest; yet if you cut it asunder, the extremes will fly from one another forcibly enough to manifest, that they were before in a state of tension. But because the bow and string were brought into a violent state by human force, I shall add, that there are several bodies, on which no such force appears to have acted, tho' they, also, are in a state of violent compression or extension, and under a strong endeavour of the parts, which seem at rest, to shrink or fly out. I have observed, that a glass, which seemed to have been well nealed, would, sometimes, crack of its own accord; and the glass-men relate, that if they take their glasses too hastily from the fire, they will be very apt to do so. I also caused a flat lump of a particular metalline glass, to be made three or four times as thick as an ordinary drinking-glass; which was so disposed to shrink upon a small degree of refrigeration, that before it was sensibly cold, it would crack, with such a noise and violence, that parts of it, of a considerable bulk, flew to a great distance from one another. Having, to preserve a particular liquor of moment, inclosed it in a strong vial, with an exquisite glass stopple, and set the vessel upon the edge of a window, in a high and secure place, that it might not be moved; it continued there for above a year. The liquor was of such a nature, that if any one had, tho' but for a moment, taken out the stopple, I cou'd easily have discover'd it. At length, as I was one day studying quietly in my closet, at a considerable distance from the place where the vial stood, I heard a loud and brisk noise, almost like the report of a pistol; and perceiv'd something come rolling to my feet, which I found to be the thicker and larger part of the stopple of my vial, that of itself had flown off; leaving the other part so strongly and closely adjusted to the neck, that I cou'd by no means force it out. There was not the least shake made in the room to occasion this; nor any body present but my self. If you take a piece of red-hot copper, and hold it over a sheet of white paper, you will perceive numerous flakes to fly off, with a little noise, sometimes as far as the edges of the paper; which flakes seem, from their brittleness and colour, to be parts of the metal vitrified by the fire, and afterwards by a too hasty refrigeration shrinking so violently, as to crack and leap from one another, like the contiguous parts of the string of a viol, which breaks by the moisture of the air. An expert artificer in metalline concaves told me, he usually observed them to shrink upon refrigeration. And the like I have observed in iron of a great thickness, and purposely fitted to a hollow body of metal, which it would not enter when it was heated, tho' it would, when it was cold. But that metals may shrink, and do so with a very considerable force, appears from hence, that the same artificer, after he had made some large concaves of an unfit mixture of metals, and removed them carefully from the fire, lest they should cool too fast, observed, that when they came to be farther refrigerated, they



they would crack with a great noise. Another tradesman, whom I often employ, complained to me, that, having cast a kind of bell-metal upon a very strong solid instrument of iron, of a surface considerably large, tho' the metal was suffered to cool in a warm room, from about eight a clock on *Saturday* night, till ten or twelve on *Monday* morning, and was then considerably hot to the touch; yet, shrinking from the iron, which would not shrink with it, it crack'd in several places, with a noise, equal to the report of a pistol; tho' the metal was an inch and a half, or two inches thick. And the same person shewed me a large cylinder of iron, about which a coat of bell-metal had been cast some days before, on which there was a crack near one end, made by the coldness of the iron, though the thickness of the bell-metal exceeded an inch. Nor is it only in such mixtures as bell-metal, which may be very brittle, but even in a metal malleable, when cold, that the like phenomenon will sometimes happen; as I learn'd from another artificer, who affirmed to me, that having cast a ring of brass, about a cylinder of iron, he found, that when the metal began to cool, the parts shrunk from one another, so as to leave a crack, which he was obliged to fill with solder, quite cross the breadth of the ring; tho' this was above an inch thick.

Now, these experiments seem to teach, that a body may be brought into a state of tension, as well by expansion with fire, as by the action of an external agent; and this state of contraction, and compression, will be illustrated by a well-strung bow. For, as that is brought to a state of compression by the force of the archer; so by the elastical force of the bow, the string is brought into a violent state of tension, as is evident by cutting it; for then both the bow will fly suddenly outwards, and the parts of the string swiftly shrink from one another. And according to this doctrine, the effect of other bodies upon such as are thus brought into, what men call, a preter-natural state, is not to be judged barely according to vulgar conceptions, but with respect to this latent disposition of the patient; for instance, tho' a slack string of a violin, will not be hardened by the vapours of the air in moist weather; yet a neighbouring string of the same instrument, tho' perhaps much stronger, being screwed up, will be so affected with those vapours, as to break with noise and violence. And so when one part of a piece of glass is made as hot as possible, without appearing discoloured to the eye, tho' a drop or two of cold water have no effect upon the other part of the same glass, yet if they touch the heated part, whose usual extension is altered by the fire, which vehemently agitates the component particles, the glass will crack. Having met with several pieces of glass, which I had reason to think were of a texture or temper, very different from the ordinary sort; I try'd whether some of them were not more brittle and elastic, than their thickness gave room to imagine: but in several the experiment

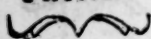
PHYSICS.

would not succeed, especially if their figure were inconvenient; yet with others I had very good success; particularly with some shaped almost like the sharper end of the neck of a receiver. For tho' these pieces of glass were much thicker than such necks, or six times as thick as the usual drinking-glasses, yet I several times, by obliquely scratching, or rather stroaking them on the inside with the head or point of a pin, made them forcibly burst to pieces in my hand. In which surprizing effects of so languid a motion, the matter of the glass seem'd to contribute, tho' much less than the texture it obtain'd by the peculiar way of ordering it in the fire and the air. And if it is possible to assign other causes of these phenomena, than such as we have mention'd, it will not much concern us; for, whatever the latent cause of the breaking of the bodies may be, the manifest circumstances of them suffice to shew, that bodies, which, as to sense, are in a natural state of rest, may be in a violent one, as to tension, and have, either upon the account of the texture of the parts among themselves, or upon that of some subtile matter; or other physical agent, a strong endeavour to fly off, or recede from one another. I might here also alledge, the relation of an honest experienced artist, whom I often chose to deal with for precious stones. For, once considering a large lump of matter with him, which contained several stones, that he took for coarse agats, and which were joined together by a cement, that in most places was harder than ordinary stones, and bore a better polish than marble, I observed to him, that there remained several large cavities in this cement, which seem'd to have contained such stones as now made part of the lump; upon which he inform'd me, that several of the stones grew whilst they were lodged in those cavities: and when I told him, that tho' I had been long of an opinion, that stones may increase after their first formation; yet I did not see how any such thing appeared by those we were now examining; he assured me, that these stones, after they were first formed, really tended to expand themselves by virtue of some principle of growth, which he could not intelligibly describe; but that they, being lodged in a cement, extremely hard, and, therefore, not capable of being forced to give way, their expansive endeavour was rendered ineffectual, but not destroyed; so that when, afterwards, they came to be taken out of the cement, wherein they were bedded, having their sides now no longer wedged in, they quickly expanded themselves, as if it were by an internal, and violently compressed spring; and would presently burst asunder, some into two, and others into more pieces; whereof he gave me some, declaring, he had taken up these stones himself, naming the place, which was not very far off; that all he had told me, was from his own repeated observation; and that I needed not suspect the strokes, employed to force the stones out of their beds, made them break: for besides, that many of them, which, it seems, were not compress'd

press'd enough, remain'd entire; several of those, which broke, were taken out, without offering them any such violence, whereto their busting could, with any probability, be ascribed. Faint strokes and attritions may produce more lasting and operative motions, among the insensible parts of compact and solid bodies, than would be readily imagin'd; for having often caused thin glass vessels, and especially urinals, to be cleaned with sand and water, tho' they wou'd not appear from hence to have receiv'd the least injury, but continue entire perhaps for several hours; yet they wou'd afterwards break, of themselves, with noise. But as others, thus cleansed, have still remain'd without flaw for a long season; this cracking seems principally to depend upon the peculiar texture of the glass in particular vessels, arising from an undue mixture of the ingredients, or a too hasty or unequal refrigeration of the parts of the metal.

8. *One principal reason why such motions as we speak of, are overlooked, is, that we scarce ever take notice but of those motions of solid bodies, where- in one whole body drives away another, or at least visibly hits against it; whilst many effects proceed from the intestine motions, produced by the external agent, in, and among the parts of the same body.* *Many effects arise from intestine motion.* This observation is likely to be more readily understood, than granted; and therefore, by way of proof, I shall offer the following experiments. We caused the moveable part in a large brass stop-cock, to be nimbly turned backwards and forwards, in the contiguous cavity made to receive it: and tho' this motion of the key were made only by the bare hand, yet in a short time the mutual attrition of the contiguous parts, made so brisk an agitation in the other, that the metal itself swelled, so that the key could no more be turned, but remained fixed, as if it had been wedged in; whence to make it work as before, it was necessary, by cooling, to let it shrink a little, and so take off the mutual pressure of the key, and the other part of the stop-cock. Nor is this to be looked on as a casual experiment; for, besides that it was made more than once, and is very agreeable to some other trials; a maker of such instruments complained to me, that he was several times forced to intermit his work, and plunge his instrument into cold water, before he could, by grinding, adjust the key to the cavity it ought to fit. The next instance, is afforded us by the known experiment of passing a wet finger upon the orifice of a drinking-glass almost filled with water; for tho' the eye does not immediately discern any motion arising from the pressure of the finger, made by one part of the glass upon another; yet, that a vibration is thereby produced, may be argued by the dancing of the water, the numerous drops that are made to leap quite over, and others that are tossed up to a considerable height into the air. And that there may be considerable motions in the sides of the glass, tho' it does not break, seems probable, because a drinking-glass being artificially cut in a spiral

PHYSICS.



line, invested and shaken; will vibrate up and down so, as to lengthen the glass above a quarter of an inch; yet, being set upright again, it will resume its former figure, and appear entire.

That two pieces of iron rubbed against one another, will acquire heat, is not hard to be believed; but that an edge-tool of hardened steel, should undergo a manifest and permanent change in its texture by friction, may not seem so likely; yet experience shews, that such an one, by turning, and shaving off the parts of metal, may be brought to look of a bluish and yellowish colour, and become so soft, as to be useless in its former capacity, till it be again artificially hardened. A famous jeweller told me, that when he polishes sapphires, rubies, and some other sorts of hard gems, upon his mill, they would seem, when the attrition had made them very hot, to be all on fire, like so many little coals; and that each of them had the light it afforded, tinged with the colour proper to the stone; so that the ruby gave a red light, the sapphire a blue, &c. And a skilful cutter of diamonds, and polisher of gems informed me, that sometimes when he polished certain stones, especially large rubies, but perhaps not thick, he could plainly perceive, that the stone gaped at and near the edge, as if it begun to be crack'd; which sign admonished him immediately, to slacken the motion of his mill, lest the stone should absolutely burst; which if it did not, he could perceive no flaw in it, when thoroughly cold, but it appeared as intire as ever. He added, that once having given too great a degree of heat to an oriental topaz, it crack'd upon the mill, so that one part quite separated from the rest, and spoiled the stone in the capacity of a gem. And a merchant, who bought a fine rough diamond in the *East-Indies*, valued at an hundred pounds, told me, that it spontaneously crack'd upon his hands, and became of little value, but as a rarity: and I cou'd not but wonder, to see so fair and hard a stone so oddly spoil'd with clefts. But the merchant, upon complaint of his loss, learn'd from those of more experience, that this was no such strange thing as he imagined; the like having happen'd to others. Nor is it always necessary, that the matter which makes the parts of an inanimate body work considerably on one another, should be either very hard, or impetuously moved. For, having some short bars of fine tin, I resolv'd to try whether, merely with my naked hands, I could not procure a considerable internal commotion among its parts; and accordingly laying hold on the two ends of a bar, I slowly bent it backwards and forwards, till it broke in the midst; when, I perceived, that the middle parts had considerably heated one another.

What use may be made of this experiment, as to the hidden cause of elasticity, belongs not to this place; however, if the restitution of a springy body, forcibly bent, proceeds only from the endeavour of the compress'd parts themselves, to recover their former state, one may take notice of the elasticity, that iron, silver, and brass acquire by ham-

PHYSICS.
hammering, among the instances, that shew, what, in some cases, may be done by a motion, wherein the parts of the same body are, by an almost unheeded force, made to act upon one another. The foregoing examples may also suffice, to shew how men are often unjustly prepossessed, that nothing considerable is to be expected from the motion of a body against another, unless the former makes a manifest percussive, or trusion of the latter. But, because this prepossession prevails especially in cases, where the body, which is to affect the other by friction or attrition, is itself soft or yielding, I shall add a few instances to remove the prejudice. An artist, eminent for grinding of optical glasses, confessed to me, that sometimes, when he went to polish his broader glasses, tho' but upon a piece of leather, sprinkled with puttee, the friction did so heat, or otherwise agitate the parts of the glass, as to make it crack from the edge to the middle; which seemed the more strange, considering what intense degrees of heat, glasses will endure without cracking, if the fire be but gradually applied; as this artist's glasses must have been gradually heated. But it may be worth inquiry, whether in this case, the whole work be performed by mere heat, or whether there intervene not a peculiar kind of motion, into which some bodies are disposed to be put by a peculiar kind of friction, that seems fitted to produce in elastic substances such a vibrating motion, as may have some considerable effects, not usually produced by moderate heat, nor always by an intense one. The trembling of the parts of a drinking-glass, and the visible vibration of the strings of a bass-viol, upon peculiar sounds, may give countenance to this conjecture. And that in some bodies, such a tremulous motion is producible, by rubbing them on so soft a thing as wool, or upon a piece of cloth, I found by this experiment. We cast into a hollow vessel, very smooth within, and of an almost hemispherical figure, several ounces of good melted brimstone; and having suffered it to cool, and taken it out, the convex surface appear'd well polished; then, this lump, being briskly rubbed in the same line, forwards and backwards, upon a cushion, in a still place, I could, by holding my ear to it, and attentively listening, plainly hear a crackling noise made by the agitated parts, which continued in a brisk, and perhaps a vibrating motion for some time after the friction was ended. And that there may be a considerable commotion produced among the internal parts of bodies, by rubbing them against soft ones, I have often observed from the steams produced by rubbing good sulphur upon my clothes: and have found the like effect from much harder, and closer bodies rubbed against one another. For having purposely rubbed two human *calculi* against each other, they quickly afforded a rank smell of stale urine. And diamonds themselves will, by rubbing them upon woollen clothes, be made electrical; which seems to argue, that their parts are thereby set in motion. And that this commotion reaches to the internal parts, I am apt to think, because I have a diamond, that;

PHYSICS. that, by well rubbing against my clothes, will, for a little while, shine in the dark; which is the same phenomenon I have produced in the king's large diamond, by giving it one brisk stroke with the point of a bodkin; where the light, which presently appeared in the gem, seemed not referable to any thing so likely, as to the sudden commotion made in the internal parts of it.

It deserves to be inquired what kinds of modification of motion there are, and what effects they may have in the parts of solid bodies. For tho' the stones used by the *Italian* glass-men, are very hard, and have afforded me sparks of fire by collision; yet by rubbing them a little, one against another, I found that such an agitation was caused in their parts, as to make them yield fetid exhalations. And, possibly, glass owes the quality of emitting offensive steams to the stony ingredient. And it is remarkable, that tho' so vehement an agitation of the parts, as is given to glass by heat, when made almost red-hot, does not cause it to emit odours; yet barely by dextrously rubbing two solid pieces one against another, those fixed bodies will in a minute yield steams, sensibly and rankly fetid; tho' one would think these exhalations very much indisposed to be forced off, since they were not expelled by the vehement fire, which the glass long endured in the furnace.

There are few things shew better, both how the parts of unorganiz'd bodies communicate their vibrating motions to one another, and how brisk those motions are, than what happens upon striking a large bell with a clapper. For tho' the stroke be immediately made, but on one part, yet the motion produced is propagated to the opposite one; and the successive vibrations of the small parts, even in so solid and close a body, run many times round; as appears by the durableness of the noise, which seems plainly to proceed from the circularly successive vibrations of the parts; for, unless they briskly trembled themselves, they can scarcely be fitted to give the air that motion, whose effect on the ear, we call ringing. And this motion of the parts of the sounding bell may be farther argued from hence, that if the finger, or some other soft body, be laid upon it, the sound will be checked, or deadened; and much more, if a broad string, tho' soft, be tied about it. And not only an attentive ear may shew, that the sound is produced by a motion, propagated circularly in the bell; but this vibration may sometimes be also felt in the tremulous motion, communicated by the trembling parts of the bell to the finger warily applied. That this motion passes circularly from one side of the bell to the other, seems manifest by the great difference of sound, observable in an entire bell, and a crack'd one; where yet all the matter, and the former figure are preserved; only the continuity, which is necessary to the circulation of the tremulous motion, is hindered at the crack. The motion of the parts is also very brisk, since if a convenient sized bell were bound about with a broad string, and then

then struck with the usual force, and which it would otherwise very well bear, that percussioſion would break it; a disorderly check being given to the brisk motion of the parts, whereof some happening to be much more agitated than others, the force of their motion surmounts that of their cohesion, and so produces a crack. But because great bells are not easily to be procured, or managed; I took that of a large watch, which had no handle put to it, except a little wooden bodkin, whose point we thrust into the hole, usually left in the middle of the basis; and this serving to keep the bell steady, we placed in the cavity of it, near the edges, some black mineral sand, or small filings of steel, copper, or the like, which must not be too small; and then striking moderately with the key against the side of the bell, we observed, that whilst it continued briskly ringing, it made many of the filings to dance up and down, and sometimes to leap and skip about; and having put a middle-sized drop of water, near the lower edge of the bell, it was easy to make it visibly tremble, and be, as it were, covered over with little waves, by a brisk stroke of the key on the opposite side. And this effect was more conspicuous, when we placed a very large drop of water near the edge, on the convex side of a hand-bell, whose clapper was kept from touching the inside of it. And to obviate their jealousy, who, not having seen the manner of the above-mentioned motion of the sand, might suspect it was produced by the impulse, which the bell, as an intire body, received from the percussioſion made by the key; we several times forbore putting in the filings, till after the stroke had been given; which shews, that the dancing of the minute bodies proceeded from the brisk vibrations of the small parts of the bell, which, at the same time, striking the air also, produced a ringing sound, that might very well, as it did, out-last the skipping of the filings; the exceedingly minute particles of the air, being much more easy to agitate, than the comparatively gross and heavy corpuscles of the powder: and this was the success of our experiment in a bell, that little exceeded an inch and an half in diameter.

These observations I presume will shew, that such local motions, as are usually, either passed over unregarded, or thought not worth the notice, may have a considerable operation, if not upon the generality of bodies, yet upon such as are peculiarly disposed to admit it; and so have a considerable share in the production of several phenomena of nature, which are commonly referred to less genuine, and less intelligible causes.

T H E MECHANICAL PRODUCTION O F MAGNETISM.

S E C T. I.

THough the virtues of the load-stone are reckon'd among qualities the most occult, yet I shall attempt to shew, that some, even of these, may be introduced into bodies, by mechanical changes.

*Iron may act
as a load-stone.*

And, 1. To shew that magnetism proceeds not from the substantial form of the load-stone; a piece of steel fitly shaped, and well excited, will, like a load-stone, have its determinate poles, and with them point north and south; it will attract other pieces of iron and steel, and, which is more, communicate to them the same kind of virtue, with itself; and these faculties it possesses, not as light and transient impressions, but settled powers, and may retain them for many years, if the load-stone, to which it was duly applied, were vigorous. Now, in a piece of steel or iron thus excited, it is plain, that the magnetic operations may be regularly performed, for succeeding years, by a body, to which the form of a load-stone doth not belong; since, as it had its own form before, so it retains the same still; continuing as malleable, fusible, &c. as an ordinary piece of the same metal unexcited: so that, if there be introduced a fit disposition into the internal parts of the metal, by the action of the load-stone, the metal, continuing of the same species it was before, will need nothing, but the continuance of that acquired disposition, to make it produce magnetical effects. And if this disposition, or internal constitution of the excited iron be destroyed, tho' the form of the metal be not at all injured, yet its power of attraction will be abolished; as appears, when such an excited iron is made red-hot in the fire, and suffered to cool again.

A load-

A load-stone, also, may easily, by ignition, be deprived of its power of sensibly attracting iron, and yet continue a true load-stone in other capacities; which, according to the vulgar philosophy, ought to depend upon its substantial form: and the load-stone thus spoiled may, notwithstanding this form, have its poles altered, at pleasure, like a piece of iron.

Magnetical qualities may be mechanically produced, destroy'd, or alter'd, in the load-stone and in iron.

And, tho' it be generally taken for granted, that in a sound load-stone, never injured by the fire, not only the attractive power, but the particular virtue, which it hath, to point constantly, with one of its determinate extremes, to one determinate pole, flows immediately from its substantial, or at least essential form; yet this form, remaining undestroyed by fire, the poles may be changed: for taking a very small fragment of a load-stone, I found, that by applying sometimes one pole, and sometimes the other, to the poles of a very vigorous load-stone, I could change the poles of the little fragment; tho' by applying a larger piece, I was not able, in many more hours, than I employed minutes before, to make any sensible change of the poles. And this I hope may shew, that, how unanimously soever men have deduced all magnetic operations from the form of the load-stone, yet some internal change of pores, or other mechanical alterations, or inward disposition, either of the excited iron, or of the load-stone itself, will disable, or enable a body to perform some determinate magnetical operations. I shall now add some farther particulars, to make it probable, that magnetical qualities may be mechanically produced or altered.

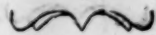
2. I have often observed in the shops of artificers, that, when well-tempered tools are heated by attrition, and apply'd to filings, or chips of steel, or iron, they will take them up, as if the instruments were touched by the load-stone: but as they will not do this, unless they are excited by friction, which makes a great commotion in the inner parts of the steel; so they retain not such a vigorous magnetism, after they are grown cold again: as appears by barely rubbing a piece of steel against the floor, till it gains a sufficient heat; for whilst it continues so, it discovers a manifest attractive power, but loses it upon growing cold.

3. 'Tis, likewise, observed, that the iron bars of windows, by having stood very long in an erect posture, may grow magnetical; so that if you apply the north point of a poised needle to the bottom of the bar, this will drive it away, and attract the southern; and if you raise the magnetic needle to the upper part of the bar, and apply it as before, this will draw the northern extreme, which the other end of the bar repelled; probably, because the bar is, in tract of time, by the continual action of the magnetical effluvia of the terraqueous globe, turned into a kind of magnet, whose lower end becomes the north-pole of it, and the other the south.

PHYSICS.

4. I have found, indeed, that, if a bar of iron, which has not stood long in an erect posture, be but held perpendicular, the experiment will succeed; but then this virtue, display'd by the extremes of the iron, will be so transient, that if the bar be but inverted, and held again upright, that end, which just before was the uppermost, and drew the north point of the needle, will now, being lowermost, drive it away; which will not happen to a bar, that has been for some years kept in the same position. So that, since length of time is requisite to make the verticity of a bar of iron so durable, that the same extreme will have the same virtues, with regard to the magnetic needle, whether it be the upper, or the lower end of the bar; it seems not improbable, that by length of time, the whole magnetic virtue of this iron may be increased, and, consequently, some degree of attraction acquired. And from hence, I shall endeavour to explain that strange phenomenon, which is reported to have happened in *Italy*, the conversion of an iron-bar into a load-stone, whereof a piece was kept, amongst other rarities, in the repository of *Aldrovandus*. For, considering the greatness of its specific gravity, the malleableness, and other properties, wherein iron differs from load-stone, I cannot easily believe, that, by such a way, as is mentioned, a metal should be turned into a stone. Indeed, the story is imperfectly told; the chiefest and clearest thing in it being, that at the top of the church of *Arimini*, a great iron-bar, placed there to support a cross of an hundred pound weight, was, at length, turned into a load-stone. But whether the reality of this transmutation was examined, and how it appeared, that the fragment of the load-stone, presented to *Aldrovandus*, was taken from that bar of iron, I am not satisfied by the narrative. Therefore, considering the great resemblance I have sometimes seen in colour, besides other manifest qualities, betwixt some load-stones, and some coarse, or almost rusty iron, I am tempted to think, that those who observed this iron-bar, when broken, to have acquired a strong magnetical virtue, which they never dreamed, wou'd be communicated in tract of time, might be easily persuaded, by this virtue, and the resemblance of colour, that the iron was turned into load-stone; especially, they being prepossessed with that *Aristotelian* maxim, whence the relator would explain this phenomenon, that similar things are easily changed into each other.

5. But, leaving this as a bare conjecture, we find, that what virtue an oblong piece of iron may need a long tract of time to acquire, by help only of its position, may be soon imparted to it, by means of the fire; as is very observable in tongs, and such like iron utensils, which have been set to cool, leaning against some wall or other prop, that kept them in an erect posture; which renders it probable, that the great commotion of the parts, made by the vehement heat of the fire, disposed the iron, whilst it was yet soft, its pores lax, and parts more pliable, to receive much quicker impressions



ons from the magnetical effluvia of the earth, than it would have done, if it had still been cold. And it is very remarkable, what different effects are produced, by the operation of the fire, upon two magnetic bodies, according to their respective constitutions. For, by keeping a load-stone red hot, tho' you cool it afterwards in a perpendicular posture, you may deprive it of its former power of attracting. But a bar of iron being heated, and set to cool perpendicularly, thereby acquires a manifest verticity. Of which differing events, possibly the reason is, that the peculiar texture and constitution which makes a load-stone, somewhat more than an ordinary ore of iron, it's usual ingredient, being spoiled by the violence of the fire, 'tis left in the condition of common iron, or iron-ore; whereas the fire softens the iron itself, agitating its parts, and making them more flexible; and by relaxing its pores, disposes it to be easily pervaded by the magnetical steams of the earth; from which it may, probably, receive its verticity: and this the rather, because, I have often tryed, if an oblong load-stone, once spoiled by the fire, be thoroughly heated, and cooled either perpendicularly, or lying horizontally, north and south, it may, as well as a piece of iron, treated in the same manner, be made to acquire new poles, or to change the old ones, at pleasure. But whatever causes the different effect of the fire upon a sound load-stone, and a bar of iron, it seems to strengthen our conjecture, that magnetical operations may much depend upon mechanical principles.

I may add, that having brought a large piece of a certain kind of *English* oker to a convenient shape; though, till it was altered by the fire, it discovered no magnetical quality; yet after it had been kept red-hot in the fire, and suffered to cool in a convenient posture, it was enabled to operate magnetically upon a poised needle.

6. The magnetical virtue in a body, may be abolished without destroying the substantial or essential form, and without sensibly adding, diminishing, or altering any thing, of the salt, sulphur, and mercury, whereof chymists presume iron and steel to be composed. For, it has been sometimes observed, that the bare continuance of a load-stone itself, in a contrary position to that, which, when freely placed, it seems to affect, has either changed, or sensibly lessened the virtue of it. And having a load-stone, whose vigour was very extraordinary, I lock'd it up in a cabinet; but when I had, some time after, occasion to make use thereof, I found it so exceedingly decayed, as to its attractive power, that I refused to employ it in any cases of moment.

7. But this degeneration of the magnetical virtue, which may, in tract of time, happen to a load-stone, will, in a moment, be made by the help of that stone, in an excited needle. For a well poised needle, being by the touch of a good load-stone, brought to turn one of its ends to the north, and the other to the south, may, by a con-

PHYSICS.

trary touch of the same load-stone, be deprived of the faculty it had of directing its determinate extremes, to determinate poles. Nay, by another touch, the needle may, presently, have its direction so changed, that the end, which before pointed to the north, shall now regard the south. And, to make it more probable, that the change of magnetism may be produced by mechanical operations, procuring some change of texture in the iron, I shall add, that if a rod of iron, by being heated, suffered to cool north and south, and hammered at its ends, be very manifestly endowed with a magnetical virtue, this virtue will, in a moment, be destroyed, by two or three smart blows of a strong hammer upon the middle of it. *

* Sir *Is. Newton* tells us, that, "Magnetism differs from gravity, because magnetic attraction is not as the quantity of matter attracted; and because some bodies are thus more attracted, others less, and a great number not at all. Besides, the magnetic force may be increased and diminished in one and the same body, and is sometimes much greater in proportion to the quantity of matter than the power of gravity; and in going from the magnet decreases not in a duplicate, but nearly in a triplicate proportion of the distance." *Newton. Princip. p. 368.*

Mr. Whiston lately found, that a load-stone has both an attractive and a directive power, independent one of the other; whilst iron touched by it has only the former, and will suffer steel-filings to lie along, or stand perpendicularly to its surface, and not like the stone, direct them to certain angles, with respect to its superficies and axis; that stones of a small size and virtue give as good a directive touch to needles, as the stronger and the larger; that the touch of the load-stone considerably diminishes the weight of the needle; one of $4584\frac{1}{8}$ grains, losing $2\frac{5}{8}$ grains thereby, and another of 65726 grains, no less than 14 grains; that the

absolute attractive power of armed load-stones, is as their quantity of surface; that the load-stone attracts needles which have been touched, and others which have not been touched with equal force, at unequal distances; that both poles of a stone equally attract needles before the touch, upon which it is, that one pole begins to attract one end, and repel the other; tho' the repelling pole will still attract upon contact, or at a very small distance; that the attractive power of load-stones, is in the sesqui-duplicate proportion of the distances of their surfaces, from the needle reciprocally; that the entire power of magnetism in this country, as it affects needles of a foot long, is to that of gravity, as 1 to 300; that the quantity of the magnetic power accelerating the same dipping-needle, oscillating in different vertical plains, is as the cosine of the angle made by those plains, and the magnetic meridian taken on the horizon; and lastly, that the times of oscillation and vibration in dipping, and horizontal needles, equally good, is as their lengths directly; and the actual velocity of their points along their arcs always equal. See *Whiston's Dipping-needle*, and *Philos. Trans. passim*.

S E C T. II.

THE load-stone is so strange a body, and its usefulness to mankind already so great, that it were inexcusable to neglect any phenomena that directly relate to so abstruse a subject. But in the present inquiry, I principally intend to make the load-stone rather the object, than the instrument of my experiments; by working on the very substance of the stone, not so much to advance or apply its faculties, as to weaken and destroy them, in order the better to understand them. Having, therefore, procured a considerable number of naked load-stones, most of them coarse, differing in size, shape, colour, and countries; I made several trials upon them.

*Experiments
and observations
upon the
load-stone it-
self.*

1. And, first, having made several load-stones glowing hot, and removed them from the fire till they grew cold again, I found a great disparity in the visible substance whereof they consisted, and the manifest structure of the gross parts that made them up. For some upon refrigeration, either fell asunder of themselves, or grew very brittle; others still continued intire; some of them, being broken, look'd like iron-ore; others being broken, after refrigeration, appear'd to consist of flakes of several colours, lying parallel to one another: and others again, which, as I remember, were *English*, neither appear'd compos'd of any such flakes, nor had their dark colours much chang'd by the operation of the fire, nor ceased to be solid bodies.

2. We could not, upon successively burning several small load-stones, discern any such blue sulphureous flame, as *Porta* in his natural magic relates himself to have seen, and judges to have been, as it were, the soul of the load-stone; upon the recess of which, he says, it lost its magnetic faculty; which is most commonly true as to any considerable degree of the attractive power, tho' not of the directive faculty or virtue. But *Porta* might mistake the small flame, which is often emitted even by well-kindled and glowing charcoal, (on which sort his load-stone was placed,) especially when a little blown upon, for the exhaling soul of the load-stone; or else we may suppose, that his stone was more rich in unctuous moisture than others.

3. The solidity of some *English* load-stones, led me, tho' I look'd upon them as a kind of iron-ore, to try whether they wou'd not strike fire. And having made several collisions betwixt a rough piece, and a common steel; I found it was possible, with difficulty, to obtain some sparks, tho' they seem'd small; but briskly striking a large piece of smooth load-stone, with the edge of a steel'd hammer, we produced numerous sparks, some of them of a surprizing bigness; for they

PHYSICS. they were judged to exceed the size of those usually afforded by common flints.

4. For certain reasons, I thought fit to try further, it whether were not possible, to make load-stones afford fire, without the help of iron or steel. I therefore chose two solid pieces cut almost into the form of cubes; and found that many collisions being made with them, especially at the edges, there were produced, from time to time, but not frequently, some sparks of fire; tho' neither so numerous, great or vivid, as those when the steel was employ'd.

5. I have found that if an oblong load-stone, made glowing hot, be cooled perpendicularly, the lower extremum will thereby become its north pole: and now I add, that if such a load-stone be refrigerated perpendicularly, upon the northern extremum of a much stronger load-stone; the weaker stone will receive impressions, as if it were iron, and its lower extremum not be, as before, by the magnetic effluvia of the earth, made its northern pole; but it will be contrarywise animated by the pole of the load-stone, on which 'tis cool'd; so that the lower extremum of it, will prove its southern pole, briskly attracting the north end of an excited needle.

6. By the like way of refrigeration, I also found, that a disanimated load-stone may be restored, to some degree of attractive virtue; for I try'd that a small load-stone, which, after being made red-hot in the fire, and cool'd perpendicularly upon the ground, was not able to take up a fragment of a needle; being again heated, and not only cool'd upon the pole of a strong load-stone, but suffered to rest on it a while after, soon grew vigorous enough, to take up what it could not move before.

7. I further observ'd, that tho' a load-stone which had once pass'd the fire, wou'd not, by being made red-hot, have its body open'd and fitted, to take in plentifully the magnetical steams; would yet, like a wire of iron, acquire a new verticity from a vigorous load-stone; but not be in many hours so vigorously impregnated with magnetic virtue, if it were applied cold to the pole of the animating load-stone; as it would in a very short time, if being glowing hot it were suffer'd to cool thereon.

8. It has been observ'd, that if a load-stone be made red-hot in the fire, it scarce retains any sensible attractive virtue, only it will be able, by being endowed with a magnetism from the earth, to drive away that pole of a needle which agrees in denomination with that pole of the load-stone, whereto it is applied. But this is not strictly and universally true; for in some of our *English* load-stones, it has been remark'd, that ignition does not only leave them possess'd of a directive virtue, but also a considerable attractive power; so that they will sustain a large weight of steel.

9. We took three *English* load-stones, that appeared to be of a very compact substance; two of them not near half an inch in length; the other much greater, being about an inch long, and of a considerable breadth, yet of small thickness: these were made red-hot in a fire of well kindled charcoal; and when they thorowly glowed, we removed them, one after another, and soon set each upon a plate of silver; and severally applying a capp'd load-stone to them whilst yet red-hot; it seem'd manifest that the stone had not then so strong an effect on them, as if they were not red-hot: but, when they ceas'd to glow, tho' they were still intensely hot, the armed load-stone had a more powerful operation on them, by way of attraction and sustentation, than before; and, also, even than after the same stones were grown cold.

10. This experiment was repeated with the two smaller magnets and the greater, with the like success: and when they were grown cold, they did, notwithstanding their having been twice ignited, discover some little magnetism, if apply'd to the end of a well-excited magnetic needle, nicely pois'd, with its centre of gravity upon the point of an ordinary needle. And, I found that the bigger of these three load-stones, after the first, if not also after the second ignition, moved the magnetic needle more briskly than one would have expected; and being thrust into filings of steel, and then taken out, it carried up with it and sustained a considerable number of them. Whence we may conclude, that in some load-stones of a very solid constitution, such as this was; the magnetical virtue is more radiated or permanent, than in the generality of other magnetic bodies: this stone being the first wherein I observ'd, after I had thorowly ignited it, any attractive virtue able to take up filings of iron.

11. We took the same load-stone that was employ'd about the last experiment, and having again made it red-hot, in the fire, suffered it not to cool leisurely in the air, as before, but quenched it, in a basin of cold water; intending thereby to make a double variation of the experiment; first, by cooling it hastily; and next, by cooling it in a fluid vastly more dense or ponderous than the air. The event of the trial was, that, upon the immersion of the red-hot stone, there fell off some flaky matter, as if it had been scales of iron; and the stone, when cold, would not take up any filings of iron, as before it did; so that it appear'd to have lost much of the virtue it so lately had; tho' it retain'd the power to move a well-pois'd needle, if it were held near, on either side of the point of it.

12. A black oblong load-stone, of a similar substance, and weighing near three drams, having been made to glow in a fire of well-kindled charcoal, and to continue in that state for some minutes; being weighed again as soon as it was cool'd, lost about $\frac{1}{8}$ of a grain in weight, and much of its black colour.

PHYSICS.

13. A lump of iron-ore, which look'd almost like a white stone rather than common-ore, and about the bigness of two eggs; being apply'd, in several of its parts, to an excited needle, did not appear to move it manifestly. But being afterwards made glowing hot, and kept so for a while, and then cooled; it did in those parts, which seem'd by their new colour to abound with metalline corpuscles, manifestly attract the north end of the needle. And this was tryed, both with a needle of our own touching, and by the mariners needle, whose *Flower-de-Luce*, the burnt ore manifestly drew.

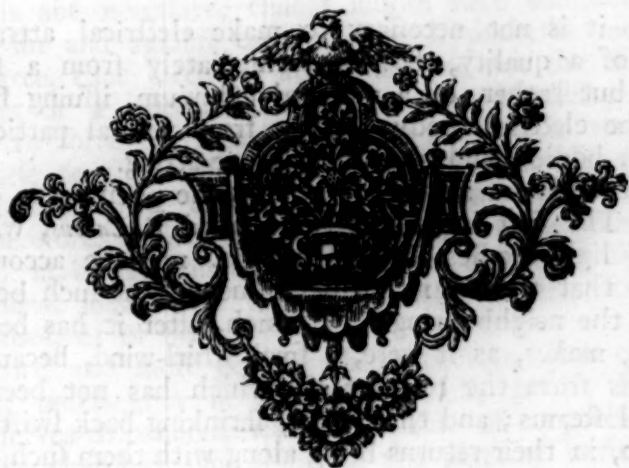
14. A brick that had not been us'd, being saw'd length-ways into two equal pieces, and each of these being heated red-hot in the fire for a pretty while, and afterwards suffer'd to cool north and south; thereby acquired a magnetical verticity; and with that end which in cooling respected the south, faintly drew the *Flower-de-Luce* of the mariner's needle; and with the other end, somewhat more vigorously drove it away, and a little attracted the other extrem of the needle.

15. We took a black load-stone, and having by degrees beaten it small, without suffering it to touch any iron or steel vessel, or instrument; we set aside the grosser grains, and upon some of the finer powder pour'd the spirit of common salt, which had, at first, a sensible operation upon it, by producing fetid fumes, and making a kind of ebullition, as that menstruum usually does upon filings of iron or steel. Nevertheless, being kept for a night or two in digestion, it drew a high tincture; and tho' this was not at all, like the solution of iron in spirit of salt, green, but of a yellowish brown, not very remote from redness; yet a little of it being dropt into a fresh infusion of galls, presently turned it to an inky substance, which in some positions appear'd bluish, as a tincture or light solution of steel would have done. And having carefully made a solution of load-stone, with good *Aqua regia*, it was thought to be a fine solution of gold.

16. Having, caus'd a weak load-stone to be heated red-hot, and afterwards to be beaten very fine, I digested spirit of salt upon it; which in a few hours acquir'd a tincture, almost like that of a troubled solution of gold. It strongly relish'd of iron, and a little being dropp'd into the infusion of galls, turn'd it immediately into an inky liquor. Part of this solution being gently evaporated, grew thick like an extract, but did not seem dispos'd to shoot into crystals; yet another part of it, precipitated with the salt of tartar, much like a solution of vitriol; and another with spirit of fermented urine, gave a large yellowish red precipitate.

17. A

17. A red mineral, of a consistence between stony and earthy, was by me judg'd to be a kind of iron-ore, tho' having powder'd some of it, I could not find that a good load-stone would attract any part thereof; I, therefore, caus'd this red powder, wetted with linseed oil, to be kept, for about two hours, glowing hot, in a crucible; by which means it was turn'd blackish. This dark colour'd powder being taken out, and suffer'd to cool, would readily adhere to the same load-stone, almost as if it had been a heap of filings of iron. But the operation of the fire, perhaps, contributed as much as the linseed oil, to this change: for, a parcel of the red powder being kept ignited in a crucible, without the liquor, afterwards appeared magnetical.



MECHANICAL PRODUCTION

O F

ELECTRICITY.

THAT it is not necessary to make electrical attraction the effect of a quality, flowing immediately from a substantial form, but rather, of a material effluvia, issuing from, and returning to, the electrical body, appears from several particulars observable in such bodies, and their manner of acting.

The hypotheses advanced to solve the phenomena of electricity.

Different hypotheses are advanced to solve the phenomena of electrical attraction. The first is that of the learned *E. Cælius*, who thinks the drawing of light bodies by amber, &c. may be accounted for, from supposing, that the steams, which issue out of such bodies, disperse and expel the neighbouring air; which, after it has been driven off a little way, makes, as it were, a small whirl-wind, because of the resistance it finds from the remoter air, which has not been affected by the electrical steams; and that these, shrinking back swiftly to the electric body, do, in their returns bring along with them such light substances as they meet with in their way. And upon this occasion I offer it to be considered; whether by the gravity of the atmospherical air, surmounting the specific gravity of the rarified atmosphere about the amber, the attraction may not, in several cases, be either caused or promoted. Another hypothesis is that of Sir *Kenelm Digby*, and others: according to which, the amber by being chafed, is made to emit certain rays of unctuous steams, which, when they come to be a little cooled by the external air, are somewhat condensed; and having lost of their former agitation, shrink back to the body, whence they sallied, and carry with them those light bodies, to which their farther ends happen to adhere, at the time of their retraction. And this way is employed also by the learned *Gassendus*, who adds, that such electrical rays being emitted, several ways, and consequently crossing one another,

ther, get into the pores of the light body to be attracted, and, by means of their crossing, take the faster hold of it, and have the greater force to carry it along with them, when they shrink back to the body, whence they were emitted.

A third hypothesis is devised by *Des Cartes*, who dislikes the solutions of others, chiefly because he thinks them not applicable to glass, which he supposes unfit to yield effluvia, tho' it be an electrical body; and therefore attempts to account for electrical attractions, by means of certain particles, shaped almost like small pieces of ribband, which he supposes to be formed of subtile matter, harboured in the pores of glass: but this is very doubtfully proposed, by the author, and seems to be embraced upon a mistake. He says, that electrical effluvia, such as are supposed to be emitted by amber, wax, &c. cannot be imagined to proceed from glass; which supposition I grant is plausible, but cannot allow it to be true. For as solid a body as glass is, yet if you dexterously rub, for two or three minutes, two pieces of it against one another, you will find, that glass is able to emit very strong effluvia.

But it is not necessary, that I should here consider, all that has been said for and against each of the hypotheses mention'd; since they all agree, that electrical attractions are not the effects of a mere quality, but of a material efflux from the attracting body; and all endeavour to solve the phenomena in a mechanical way, without having recourse to substantial forms, and inexplicable qualities, or so much as taking notice of the hypostatical principles of the chymists. It may, therefore, suffice, that I here mention some phenomena, which, in general, make it probable, that amber, &c. draw light bodies, by virtue of some mechanical properties, either of the attracting, or attracted bodies, or of both.

1. The first and most general observation is, that electrical bodies attract not, unless they be warmed; which, tho' it does not always hold, yet serves to countenance our doctrine of corporeal effluvia. For it is known, that heat, by agitating the parts of a fit body, solicits it to send out its effluvia, as is obvious in odoriferous gums and perfumes, which, being heated, emit their fragrant steams both farther, and in greater plenty, than otherwise they would.

2. It has been observed, that amber, warmed by the fire, does not attract so vigorously, as if it acquires an equal degree of heat, by chafing: so that the modification of motion, in the internal parts, and in the effluvia, may, as well as the degree of it, contribute to the attraction. And the effect may often be promoted by employing both these ways successively; as I manifestly found, by first warming amber by the fire, and presently after chafing it upon a piece of cloth: as if the heat of the fire had put the parts into a general, but confused agitation; to which it was easy for the subsequent attrition to give

PHYSICS.

give a convenient modification, in a body whose texture disposes it to become vigorously electrical.

3. Another observation is, that electrical bodies require a polish, as well as attrition; and tho' I doubt whether the rule be infallible, yet weaker electrics require to be as well wiped, as chafed; and even good ones will have their operation promoted by the same means. For wiping, is a kind of attrition, and frees the surface from what might choak the pores of the amber, or hinder the efflux of its steams.

4. It is likewise observed, that as tho' magnetical steams are so subtile, that they penetrate thro' all kinds of mediums hitherto known; electrical effluvia are, like those of some odoriferous bodies, easily checked in their progress; since the interposition of the finest linen or sarinet, is sufficient to hinder all the operation of excited amber upon a straw, or a feather, plac'd ever so little beyond it.

5. It has been also observed, that the effects of electrical attraction are weakened, if the air be thick and cloudy; and especially, if a south wind blows; that electrics display their virtue more faintly by night than by day, but more vigorously, in clear weather, and when the wind is nothertherly; and that those bodies, which are but faintly drawn, when the weather is clear, will not be at all moved, when it is thick and cloudy.

6. We have also observed, that several concretes, which are notably electrical, abound in a subtile matter, capable of being manifestly evaporated by heat, and rubbing. Thus, most resinous gums, which draw light bodies, do also, being moderately solicited by heat, emit steams; pieces of sulphur, upon due attrition, give a sulphurous smell; and the piece of amber, which I most employ, and is somewhat large, and very well polished, being rubb'd upon a piece of woollen cloth, will emit steams, manifestly scented of amber.

7. It agrees very well with what we have said of the corporeal emanations of amber, that its attractive power will continue, after it has been once excited. For the attrition, having caused an intestine motion in its parts, the heat thereby excited ought not to cease, as soon as ever the rubbing is over, but to continue capable of emitting effluvia for some time afterwards, longer or shorter, according to the goodness of the electric, and the degree of the commotion made; all which, joyned together, may sometimes make the effect considerable: and by this means, on a warm day, I with a certain body, not bigger than a pea, but very vigorously attractive, moved a steel needle, freely poised, about three minutes after I had left off rubbing it.

8. It seems not impossible, that electrical effluvia should insinuate themselves into the pores of many other bodies, because I have found them subtile enough to attract, not only spirit of wine, but that fluid, we call smoke. For, having well lighted a wax-taper, I blew out the flame, and when the smoke ascended, in a slender stream, held,

held at a convenient distance from it, an excited piece of amber, or a chafed diamond, which would manifestly make the ascending smoke turn out of its former line, and beat, as it were, against the electric; and this, if vigorous, would act at a considerable distance, and seem to smoke for a tolerable while after.

9. That this attraction depends not on any peculiar sympathy between an electric, and the body whereon it operates, seems the more probable, because amber attracts not only one determinate sort of bodies, as the load-stone iron, and these bodies, wherein it abounds, but draws indifferently all bodies whatsoever, placed at a due distance from it, provided they be minute or light. But I am yet in suspense as to its attraction of fire; for, having applied a strong electric, at a proper distance, to small fragments of kindled matter, they were readily attracted, and shone, whilst sticking to the body; but looking attentively upon them, I found the shining sparks to be clothed with light ashes, which, in spite of my care, had been already formed about the attracted corpuscles, upon part of the fire's expiring; so that it remained doubtful, whether the kindled corpuscles, whilst totally such, were attracted; or whether the immediate objects of the attraction were not the new-formed ashes, which carried up with them the unextinguished parts of the fire, that chanced to be lodged in them. But as for flame, our *Gilbert* delivers it for his own experiment, that an electric will not move the flame of the slenderest candle. I have tried it with a rough diamond, extraordinarily attractive; and was not satisfied, that it attracted the flame, as it visibly did the smoke. But tho' this shou'd prove an exception to the rule, yet it may well agree with my hypothesis; since the heat of the flame might dissipate the effluvia, by means whereof the attraction should be performed. The celerity also of the motion of the flame upwards, might render it very difficult for the electrical effluvia, to divert it from its course.

10. We have found, that a vigorous piece of amber will draw, not only the powder of amber, but larger fragments of it. And, as one contrary directs to another, so this trial suggested a farther; which, in case of success, would probably argue, that in electrical attraction, not only effluvia are emitted by the electrical body; but that these effluvia fasten upon the body to be drawn, in such a manner, that the intervening viscous strings, which may be supposed made up of those cohering effluvia, are, when their agitation ceases, contracted, or made to shrink inwards toward both ends, almost as a highly-stretched lute-string, when permitted to shrink into shorter dimensions. But the conjecture itself was much more easy to make, than the experiment requisite to examine it. For we found it difficult to suspend, excite and poise an electric, so that the faint force, wherewith it attracts light substances, should procure a motion to its whole body. But, after some fruitless attempts with other electrics, I had recourse

PHYSICS. to a very vigorous piece of polished amber; and when we had, with the help of a little wax, suspended it by a silken string, we very well chafed one of the blunt edges of it upon a kind of large pin-cushion, covered with a coarse black woollen stuff; and then brought the electric, as soon as we could, to rest, pendulous at the bottom of the string. And thus, at length, we found, that if, as soon as the suspended electric was brought to settle freely, we applied to the chafed edge, but without touching it, the cushion, which, by reason of its rough superficies and porosity, was fit for the electrical effluvia to fasten upon, the edge would manifestly be drawn aside by the cushion steadily held: and if this was slowly removed, that would follow it a considerable way; and when this body no longer detained it, 'twould return to the posture, wherein it had settled before. And this power of approaching the cushion, by virtue of the operation of its own steams, was so durable in our amber, that by once chafing it, I was able to make it follow the cushion no less than ten or eleven times.

Electricity producible by mechanical changes.

II. Other phenomena might be added of the same tendency; but, designing here to give only some experiments about the production of electricity, it will be sufficient to relate how I have produced or destroyed this quality in certain bodies, by means of alterations, which appeared to be no other than mechanical. And (1.) Having, with a very mild heat, slowly evaporated about a fourth part of good turpentine, I found, the remaining body would not, when cold, continue a liquor, but it hardened into a transparent gum, almost like amber, and proved electrical. (2.) By mixing two such liquid bodies, as *Petroleum*, and strong spirit of nitre, in a certain proportion, and then distilling them, till there remained a dry mass, I obtained a brittle substance, as black as jet; with its superficies, where it was contiguous to the retort, glossy, as that mineral is when polished: and I found it farther resemble jet, in having an electrical faculty. (3.) Having burnt antimony to ashes, and of those ashes, without any addition, made a transparent glass, I perceived it manifested, when rubbed, a considerable electricity. And this is the more remarkable, because, as a *Vitrum Antimonii*, which is said to be purer than ordinary, may be made of the regulus of the same mineral, in whose preparation a great part of the antimonial sulphur is separated, and left among the *Scoria*; so glass of antimony, made without addition, may easily be reduced to a regulus; a body not reckoned electrical. (4.) I made some glass of lead *per se*, which also was not destitute of an electrical virtue, tho' it had but a very languid one. And this glass might easily be brought again to afford malleable lead, which was never reckoned among electrical bodies. (5.) Having warily distilled amber, by itself, that I might have an unmixed *Caput mortuum*, and continued the operation, till it had afforded a large proportion of phlegm, spirit, volatile salt, and oil, we carefully broke the retort, and took out the remaining matter in a lump, which, tho' it had quite lost its colour, being

being burnt black, and tho' grown strangely brittle; yet this *Caput mortuum* was so far from having lost its electrical faculty, that it seemed to attract more vigorously than amber itself, before it is committed to distillation. And from the instances afforded by the glass of antimony, we may learn, that when the form of a body seems to be destroyed by analysis, which dissipates the parts of it, the remaining substance may yet be endowed with electricity. From the second example, and from the common glass, which is electrical, we may also learn, that bodies, which are neither of them, a-part, endowed with electricity, may acquire that virtue in the compound substance, which they constitute.

12. To these experiments, I shall add a surprizing phenomenon, which may help to make it probable, that electrical attractions need not be attributed to the substantial, or essential form of the attractent; but may be the effects of unheeded, and fortuitous causes. That false locks of hair, brought to a certain degree of dryness, will be attracted by the flesh of some persons, I had proof in two beautiful ladies who wore them; for, at sometimes, I observed, that they could not keep them from flying to their cheeks, and from striking there, tho' neither of them had occasion for, or did use paint. When one of these beauties first shewed me this experiment, I turned it to a complement, suspecting there might be some trick in it, tho' I afterwards saw the same thing happen in the locks of the other too; who gave me leave to satisfy my self farther; and desiring her to hold her warm hand at a convenient distance from one of those locks taken off, and placed in the free air, as soon as she did this, the lower end of the lock, which was free, applied itself presently to her hand. This seemed the more strange, because so great a multitude of hairs would not have been easily attracted by an ordinary electrical body, which had not been considerably large, or extraordinary vigorous. Afterwards I inquired of some other young ladies, whether they had observed any such thing; and one of them told me, she had sometimes met with these troublesome locks; but that all she could say farther was, that they seemed to fly most to her cheeks, when they had been put into a stiff curl, and when the weather was frosty.*

* Mr. Stephen Gray, found by trial, that a feather drawn thro' his fingers acquired a degree of electricity, and would be attracted by the finger when held near it; that a human hair, after having passed three or four times between his finger and thumb, would fly to his finger at the distance of half an inch; and that the hair of a dog's ear and threads of silk would do the like. His trials also

13. Having succeeded in pieces of ribband of several colours, and half a yard long; so that the hand held at the lower end of any of them, would attract them at the distance of five or six inches. But if they imbibed the moisture of the air, their electricity would be much weaken'd thereby; tho' in this case, the fire never failed to give them a strong one. In short, he found woollen, paper, leather, wood-

PHYSICS.

13. Having moderately excited a large vigorous piece of amber, I held a downy feather so close so it, that the nearest part thereof was drawn by, and stuck fast to it; the remoter parts continuing in their former posture; then applying my finger to the erect downy part, it immediately left its posture, and applied itself to my finger, as if that had been an electrical body. And whether I offered my nail, or the pulp of my finger thereto, or held it towards the right hand, the left, or directly over the hairs or feathers, which were near the little quill, they suddenly, and for ought that appeared, equally turn'd towards them, and fasten'd themselves thereto. And to shew, that the steams, which issued out of my finger, were not necessary to attract these hairs, I applied to them, after the same manner, a little cylindrical instrument of silver, to which they bowed, and fastened themselves, as they had done to my finger; tho' the tip of this instrument was presented to them in several postures. The like success I had with the end of an iron key, and also with a cold piece of polished black marble: and sometimes the hairs so readily fasten'd themselves to these extraneous, and unexcited bodies, that I have been able to make one of them draw the feather from the amber itself. But it is to be observed, that this unusual attraction happened, only, whilst the electrical operation of the excited amber continued strong enough to sustain the feathers. For afterwards, neither the approach of my finger, nor that of the other bodies, would make them change their posture; yet as soon as ever the amber was excited again by a little friction, the feather would be disposed to apply itself again to the bodies mentioned. And lest there should be any peculiarity in that particular feather, I made trials with others, and found the experiment to answer in the same manner. I made the experiment also at different times, at some months interval, but still with the like success. And farther, I found the like success, when, in the place of amber, I substituted another electric, and particularly a smooth mass of melted brimstone.

wood-shavings, parchment, and gold-beaters skin, to be electrical, and that they not only came to the hand, or any other solid body, but attracted small bodies to them, sometimes at the distance of eight or ten inches. Some of these, also, appear'd luminous upon friction. See *Philos. Transf.* N^o. 366. p. 104.

The late Mr. *Hauksbee*, discover'd a surprizing kind of electricity in glass. A tube of that metal he found, wou'd, when rubbed, variously attract pieces of

leaf-brass at a considerable distance, and with greater force, the more the tube was heated by rubbing; tho' this it did differently, according to the different temper and constitution of the air. He also found that the effect ceased, or was destroy'd, upon exhausting the air out of the tube, but that it return'd, in a considerable degree, upon its re-admission, without any new attrition. *Hauksbee's Experiments*, p. 53.

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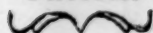
I also found, that a vigorous piece of amber, which I caused to be purposely turn'd, and polish'd for electric experiments, wou'd, in warm weather, manifestly retain the power of attracting for several minutes; and it has stirr'd a poised needle, a quarter of an hour after it had been chafed. This piece of amber, being first well rubb'd, we suspended over a straw, a feather, or other light body in a glass receiver, and presently exhausting the glass of air, we let down the amber till it came very near the straw or feather, and perceived, in some trials, that upon the least contact it wou'd raise them up, and in others, without touching, attract them.

14. But the event of electrical experiments is not always so certain, as that of many others; being sometimes much varied by seemingly slight circumstances, and now and then by some, which are altogether over-looked. And it is not so certain, as many think, whether some particular bodies be, or be not electrical. For *Kircher* reckons crystal among those gems, that have not the attractive power, we are speaking of; yet I remember not, among all the trials I have made with native crystal, to have found any piece destitute of it. A late writer, also, reciting the electrics, reckoned up by *Gilbert*, and increasing the number with some observed by himself, denies electricity to the cornelian, and the emerald. I the less wonder he should do it to the former, because I have my self in vain tryed to make any attraction with a piece of cornelian, so large and so fair, that it was kept for a rarity; yet with several other fine cornelians, I have been able to attract, very manifestly, some light bodies: and I usually wear a cornelian, which its richly endowed with electricity. And as for emeralds, I have, indeed, seen a stone, which, tho' green, had a vigorous electricity: this, however, was not a true emerald, but, which is rare, a green sapphire: and I learned of the jeweller, who cut it, that it was so far from having the softness of an emerald, that he found it even harder than a blue sapphire. Without, therefore, concluding any thing from this experiment, except, that the want of an electrical faculty might be thought a concomitant, rather of the peculiar texture of the emerald, than of its green colour, I proceeded to make trial with three or four true emeralds, and found them all somewhat, tho' not equally, electrical: and tho' by this success, I could not gain a new way to judge of true and false emeralds, yet the rule I hoped to have establish'd in these, may be of use in estimating, whether diamonds be genuine or counterfeit. For tho' glass hath a faint electricity, that of diamonds is exceeding vigorous. And I do not remember to have met with any electric of the same bulk, more vigorous, than a rough diamond I have. But as it has been observed, that diamonds attract better whilst rough, than after they are cut and polished; this seems to contradict what we said of other electrics, that they attract more vigorously, if the surface be made very smooth, than otherwise: but

PHYSICS.

the great rapidity, with which the wheels that serve to cut and polish diamonds must be moved, excites a great degree of heat in the stone; whereby, perhaps, it loses its exhalable matter so plentifully, as to impoverish it: and, perhaps, also, some little change may be hereby made in its texture, which indisposes it to emit such effluvia, as are the instruments of electrical attraction. But as I willingly leave the matter of fact to farther trial; so I do the cause of it, in case that proves true, to farther inquiry.





T H E

MECHANICAL CAUSES

O F

PRECIPITATION.

BY precipitation, I here mean such an agitation, or motion of an heterogeneous liquor, as makes the parts of it subside in the form of a powder, or other consistent body. And as chymists call the substance, which thus falls to the bottom of the liquor, precipitate; so we shall term the body, put into the liquor, the precipitant; that which is to be struck down, the precipitable substance or matter; and the liquor, wherein it swims before the separation, the menstruum or solvent. When the fall of a body is procured by a precipitant, the operation is called precipitation, in the proper or strict sense: but when the separation is made without any such addition, or when the substance separated from the fluid part of the liquor emerges, instead of subsiding, then the word is used in a more comprehensive, but less proper sense.

The very name of precipitation having, in its chymical sense, been scarce heard of in the peripatetic schools, it is not to be expected, that they should have given us the reasons of the thing. And it is likely, that those few *Aristotelians*, who have taken notice of this operation, would, according to their custom on such occasions, have recourse to some secret sympathy or antipathy between the bodies, whose action and re-action appears in this process. And thus some chymists ascribe precipitation, either to a sympathy betwixt the precipitating body and the menstruum, which makes the solvent run to the embraces of the precipitant, and so let fall the particles of the body sustained before; or to a great contrariety between the acid salt of the menstruum, and the fixed salt of the oil, or solution of calcined tartar, which is the most usual precipitant they employ. But I see not how either of these causes will reach to all the phenomena exhibited,

Precipitation, what.

Its cause enquired into.

PHYSICS.

exhibited, or give a true account of some of those, to which it seems applicable. For first, in precipitations, wherein, what they call a sympathy between the liquors, is supposed to produce the effect; this sympathy does not shew such an occult quality as is presumed, but rather consists in a greater correspondence, as to bigness, shape, motion, and pores of the minute parts, between the menstruum and the precipitant, than between the same solvent, and the body it before kept dissolved. And tho' this sympathy, rightly explained, may be allowed to have an interest in some such precipitations, as let fall the dissolved body in its pristine nature and form, only reduced to minute powder; yet in the generality of precipitations, this doctrine will scarce hold: for in some that we have made of gold and silver, in proper menstruums, after the subsiding matter had been well washed and dried; I found the powder to exceed the weight of the gold and silver put to dissolve: and the eye itself sufficiently discovers such precipitates not to be mere metalline powders, but compositions, consisting not of the combined salts alone, but of the metalline parts also; as may be concluded from the ponderosity of several of them in respect to their bulk, and from their reduction to true malleable metals.

The other chymical way of explaining precipitations, may, in a proper sense, be used on some particular occasions; but I think it much too narrow, and defective, in general. For first, it is plain, that not only salt of tartar, and other fixed alkalies, precipitate most bodies, which are dissolved in acid menstruums; as in making of *Aurum fulminans*, oil of tartar strikes down the gold out of *Aqua regis*; but acid liquors themselves, in many cases no less powerfully precipitate metals, and other bodies out of one another. Thus spirit of salt precipitates silver out of *Aqua fortis*; the corrosive spirit of nitre plentifully precipitates that white powder, whereof *Bezoardicum minerale* is made; and spirit, or oil of sulphur precipitates corals, pearls, &c. dissolved in spirit of vinegar. And I have sometimes made a menstruum, wherein, tho' there were both acid and alcalizate salts, yet I did not find, that either acid spirits, or oil of tartar, or even spirit of urine, would precipitate the dissolved substances. And I have observed, both that salts of a contrary nature will precipitate bodies out of the same menstruum; as not only salt of tartar, but sea-salt, being dissolved, will precipitate each other; and each of them apart precipitate silver out of *Aqua fortis*; and that, even where there is a confessed contrariety betwixt two liquors, it may be so ordered, that neither shall precipitate what is dissolved by the other.

The mechanical ways of accounting for precipitation.

But it will the better appear, that these chymical hypotheses are insufficient to solve the phenomena, if we proceed to observe the mechanical ways, by which precipitations may be accounted for. To precipitate, then, the corpuscles of a metal out of a menstruum, the two

two general ways are, either to add to the weight or bulk of the dissolved particles, and thereby render them unfit to accompany those of the menstruum in their motions; or to weaken the sustaining power of the menstruum, and thereby disable it to keep the metalline particles swimming any longer: and this fall of the deserted metalline parts often enlues the more easily, when the sustaining particles of the menstruum come to be too much weakened; that proving an occasion to them, disturbed in the former motion, which kept them separate, to make occurrences, and coalitions among themselves, whence their sinking becomes the effect, of both ways of precipitation; as, on the other side, there are several occasions, on which the same precipitant, that brings the swimming particles of the metal to stick to one another, likewise, by mortifying or disabling the saline spirits, or other parts of the solvent, weakens the sustaining power of that liquor.

To consider these two ways distinctly. The first more general cause of precipitation arises from such a cohesion procured by the precipitant in the solution, as renders the compounded corpuscles too heavy to be sustained. That, in many precipitations, a coalition is made betwixt the small parts of the precipitant, and those of the dissolved metal, appears by the weight of the precipitate, which, tho' carefully washed and dried, often exceeds that of the dissolved metal: for, if, having dissolved silver in good *Aqua fortis*, you precipitate it with the solution of sea-salt, in fair water, and from the very white precipitate wash the salts; the remaining powder, being dried, and slowly melted, will look much less like a metalline body, than a piece of horn, whence it takes its name of *Luna cornea*: so considerable is the addition of the saline to the metalline particles. And, that part of such additions is retained, in many cases, appears to the eye; for if you dissolve mercury in *Aqua fortis*, and into the filtered solution drop spirit of salt, salt-water, or an urinous spirit, you will have a very white precipitate; but if, instead of any of these, you drop in oil of tartar *per deliquium*, the precipitate will be of a brick, or orange colour. From which experiment, and some others, I would gladly persuade physicians, that it is not indifferent, by what means the precipitation is performed. For, by reason of the strict adhesion of many saline particles of the precipitant and the solvent, the precipitated body, notwithstanding all the usual ablutions, may have its qualities much diversified by those of the particles of the liquors, when fitted to stick very fast to it. And hence there must happen a great difference between precipitations; as any one will think, who precipitates the solution of silver with copper, with spirit of sal-armoniac, salt-water, oil of tartar, quick-silver, crude tartar, and with zink. And in the preceding examples, it is not all one, whether, to dissolve mercury or silver, you employ the subtile distilled spirits of salt, or the

From the gravity and bulk of the dissolved body.

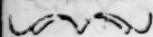
PHYSICS. the gross body, either in a dry form, or barely dissolved in common water.

That, also, the bulk of a body may greatly contribute to make it sink, or swim in a liquor, appears by obvious instances. Thus salt, or sugar, being put into water, falls at first to the bottom, and lies there, notwithstanding the air, that may be intercepted between its parts. But when, by the action of the water, it is dissolved into minute particles, these are carried up and down with those of the liquor, and subside not. The like happens, when a piece of silver is cast into *Aqua fortis*, and in many other cases. On the other side, I have observed, some bodies, that had long swam in a menstruum, whilst their minute parts were kept from uniting in it, wou'd, afterwards, by the coalition of many of those particles into bodies of a visible bulk, coagulate and subside. Thus, particularly, in urinous spirits, well dephlegmed, after they had, for a considerable time, continued in the form of a perfect liquor, numerous solid corpuscles, joining together, settled at the bottom of the glasses, in the form of saline crystals. Having, also, long kept a very red solution of sulphur, made with highly rectified spirit of urine; I observed, that, at length, the sulphureous particles, forming into little concretions, totally subsided, and left the liquor almost colourless. And hence it appears proper to mention, among the subordinate causes of precipitation, the association of the particles of a dissolved body with one another. If in what the chymists call precipitate *per se*, the mercury be indeed brought to lose its fluidity, and become a powder, uncompounded with any additional body, it will afford us a notable instance to prove, that the coalitions of particles into clusters of the same matter, will render them unfit for the motion requisite to fluidity. For this odd precipitation by fire, wherein the same menstruum is both the liquor, and the precipitate, being not all made at once, the corpuscles, which first disclose themselves by their redness, are rejected by those of the mercury, that yet remains fluid, as unable to accompany them, in the motions that belong to mercury.

And perhaps in several cases, the corpuscles of a dissolved body may become unfit to be any longer sustained in the menstruum, tho' the precipitant adds very little to their bulk; or at least much more to their specific gravity, than to that. For in many solutions made of bodies by acid menstrooms, there are either generated, or extricated many small aerial particles; and it will be easily granted, that these may be small enough to be detained in the pores of the liquor, and remain invisible there, considering what a multitude of aerial, imperceptible bubbles is afforded by common water, in our exhausted receivers. And if the corpuscles of the dissolved body, have any little cavities fit to lodge aerial particles; these invisible bubbles may make, with the solid corpuscles they adhere to, little aggregates,
much

much lighter *in specie* than the corpuscles themselves; and consequently, if the precipitant consist of particles, of such a size and shape, as are fit to expel these little bubbles, and lodge themselves in the cavities they before possessed, new aggregates will be produced, consisting of the corpuscles of the dissolved body, and the particles of the precipitant: and these aggregates, tho' they possess perhaps more room, than those, whereof the aerial bubbles made a-part, will yet be specifically heavier than the former; whereby they may overcome the sustaining power of the menstruum. And farther, it is upon account of the specific gravity of a body, and not barely of the action of the precipitant, that an aggregate of particles rather falls to the bottom, than rises to the top. For tho' the agents, that procured the coalition, render the cluster of particles of two unweildy a bulk to continue in the liquor, as parts of it; yet if each of them be lighter *in specie* than an equal bulk of the menstruum; or if they so unite, as to intercept a sufficient number of aerial bubbles between them, and so become lighter than as much of the menstruum, as they take up the room of, they will not be precipitated, but emerge; as may be seen in the preparation of those magisteries of vegetables, where some high coloured plants being made deeply to tinge the lixivium, wherein they are boiled, are afterwards, by the addition of alum, curdl'd, as it were, into coloured concretions, which being too large to swim, as they did before they united, and too light, in comparison of the menstruum to subside, mount to the top, and float there. An easier example, and more pertinent to this purpose, is afforded by dissolving camphire in highly rectified spirit of wine, till the solution is very strong. For tho' the camphire, when put, by lumps, into the spirit, sunk to the bottom of it, yet when a large quantity of water, (which is heavier *in specie* than the gum) was poured upon the solution, the camphire quickly concreted, and returned to its own nature, and soon after emerged and floated on the top of the mixed liquors. These particulars I mention, as instances of precipitation, improperly so called. But, I must here take notice of a phenomenon, which sometimes occurs in precipitations, and may at first sight seem contrary to our doctrine. For it now and then happens, that after some drops of the precipitant have begun a precipitation, if the vessel be shook, the matter already precipitated disappears, and the solvent again becomes clear, as before the precipitant was put into it. But this phenomenon doth not contradict our theory. For, when this happens, tho' that part of the solvent, to which the precipitant reaches, is made unable to support the dissolved body; yet this quantity of the precipitant is but small, in proportion to the whole bulk of the solvent. And, therefore, when the agitation of the vessel disperses the clusters of particles loosely concreted, thro' the whole liquor; that greater part, to which the precipitant did not reach before, may well be
looked

PHYSICS.



looked upon as a fresh menstruum, which is able to mortify or overpower the small quantity of the precipitant, mingled with it, and so to destroy its late operation on the body dissolved; by which means the solution returns to its former state. Thus, precipitating a brick-coloured powder out of a strong solution of sublimate, made in fair water; the subsiding matter being laid to dry in the filtre, by which it was separated from the water, would retain a deep, but somewhat dirty colour; and if, putting it into the bottom of a wine-glass, I poured upon it, either clear oil of vitriol, or some other strong acid menstruum, the alcalizate particles being disabled, and swallowed up by some of the acid ones of the menstruum; the other acid ones would so readily dissolve the remainder of the powder, that immediately the colour of it vanish'd, and the whole mixture appear'd a clear liquor, without any sediment.

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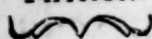
The other of the two principal ways, wherein precipitations may be effected, is by disabling the solvent to sustain the dissolved body. There are many instances, wherein this may conspire with the first way proposed: but, notwithstanding nature may sometimes employ them both together; yet in some cases they sufficiently differ. For, in the former, the fall of the dissolved body is chiefly caused by the additional weight, as well as the action of the external precipitant; but in most instances of the latter, the effect is produced, either without salt of tartar, or any such precipitant; or by some other quality of the precipitant, more than by its weight, or at least, besides the weight it adds. This premised, I observe, that the general way last proposed, contains several subordinate ways, which are more particular. And first, a precipitation may be made, if the saline, or other dissolving particles of the menstruum are rendered unfit for their former function, by particles of a precipitant, of a contrary nature. Thus gold, and some other minerals, being dissolved in *Aqua regis*, will be precipitated with spirit of urine, and other such liquors, abounding with volatile, and salino-sulphureous corpuscles, whereby they act; whence these salts themselves, tho' cast into a menstruum in a dry form, will make the like precipitations: yet the volatile particles of urinous spirits, add much less weight than salt of tartar, to the little concretions, which compose the precipitated powder. Upon instances of this kind, chymists have built that antipathy betwixt the salts of the solvent, and those of the menstruum, to which they ascribe almost all precipitations. In answer to which, farther than what has been already offer'd, I say, first, that some of those menstrooms, to which the antipathy is attributed, do, after a short commotion, friendly unite into concretions participating of both the ingredients. To shew this, I have dropt a clear solution of fixed n'tre, instead of the usual one of common salt, upon a solution of silver in *Aqua fortis*; when, the saline particles of the solvent, and those of the precipitant will, for the most part, kindly

ly form themselves into such crystals of nitre, as they were obtained from. But were this notion of the chymists true, it ought to be explained by mechanical principles. For, if the particles of the menstruum, and those of the precipitant, be so framed, that by the action of the one upon the other, there will be produced corpuscles, too big and unweildy to continue in the state of fluidity, a precipitation must ensue: but if the constitution of the corpuscles of the precipitating, and of the dissolved body, be such, that the precipitant, also, itself, is a fit menstruum to dissolve that body; then, tho' there be an union of the salts of the precipitant, and the metal, and perhaps of the solvent too, yet a precipitation will not necessarily follow; tho' the saline particles of the two liquors seemed, by the heat and ebullition excited between them upon their meeting, to shew a great and mutual antipathy. To be satisfy'd in this particular, I dissolved zink in an urinous spirit, and then put to it a convenient quantity of a proper acid spirit; but tho' a manifest conflict hence arose, yet the zink remain'd dissolved in the mixture. And for an easier experiment to the same purpose, I dissolved copper, calcined *per se*, or even crude, in strong spirit of salt; and having gradually put to it a large quantity of spirit of sal-armoniac, or fermented urine; tho' there was a great commotion raised, with hissing and bubbles, the copper would not precipitate; because this urinous spirit will, as well as the salt, dissolve the same metal; and it continued dissolved, notwithstanding their operation on one another; which operation, as well as their action upon the metalline corpuscles, appears from hence, that the green solution, made with spirit of salt alone, will, by the addition of urinous spirits, be changed either into a bluish green; or, if the proportion of this spirit be very great, into a rich blue, almost like ultramarine. And from these two experiments, we may probably argue, that when the precipitation of a metal, &c. ensues, it is not barely on account of the supposed antipathy betwixt the salts; but because the causes of that seeming antipathy do likewise, upon a mechanical account, dispose the corpuscles of the blended liquors to cohere, so as to be too unweildy for the fluid part.

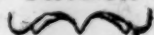
Another way, whereby the dissolving particles of a menstruum may be rendred unfit to sustain the dissolved body, is, to present them another, on which they can more easily work. A notable example of this we have in the common practice of the refiners, who, to recover the silver out of lace, and other such mixtures, dissolve it in *Aqua fortis*, and then in the solution leave copper-plates for a night. But to make the experiment with expedition; as soon as I have dissolved a convenient quantity of silver in *Aqua fortis*, I add twenty times as much of distilled, or rain-water; and then in the clear solution, hang, by a string a clean piece of copper, which will be presently covered with little shining flakes, almost like the scales of fish; and

By presenting another body to be wrought on, &c.

PHYSICS.



and these we can easily shake off, to make room for more. This may also illustrate what we formerly said, as to the subsiding of metalline corpuscles, when they unite in liquors, wherein, whilst dispersed in very minute parts, they swim freely. For here the little scales of silver seemed to be purely metalline, and there is no saline precipitant, as salt of tartar, or of urine employed to make them subside. Upon the same ground, gold and silver, dissolved in their proper menstruums, may be precipitated with running mercury; and if a solution of blue vitriol be made in water, a clean plate of steel or iron being immersed in it, will presently be over-laid with a very thin case of copper, which after a time grows thicker; but does not adhere to the iron so loosely, as to be shaken off, as the precipitated silver may be from the copper-plates. And that in these operations, the saline particles may really quit the dissolved body, and work upon the precipitant, appears by the practice of the refiners lately mentioned; where the *Aqua fortis*, which forsakes the particles of the silver, falls to work upon the copper-plates employed about the precipitation, and dissolves so much of them, as to acquire the greenish blue colour of a good solution of that metal. And the copper we can easily again obtain, without salts, by precipitation, out of that liquor with iron; and that too, remaining dissolved in its place, we can precipitate with the tasteless powder of another mineral. Besides these two ways of weakening the menstruum, a third is, by lessening or disturbing the agitation of the solvent. And, indeed, since we find by experience, that some liquors, when they are heated, will either dissolve some bodies, they would not touch when cold, or dissolve them more powerfully when hot than cold; it is probable, that what considerably lessens such an agitation of the parts of the menstruum, as is necessary to keep the dissolved body in a state of fluidity, should occasion it again to fall to the bottom. I could give several examples of the precipitating power of cold in slow operations; for there are several solutions, and particularly that of amber-grease, which remaining fluid all the summer, will subside in the winter. And the like may be sometimes much sooner observed in the solutions of sulphur, made in certain oleaginous menstruums; and I have now and then had some solutions, and particularly one of benzoin, made in spirit of wine, which surprized me with the turbidness they would acquire, upon a suddain change of weather to cold, tho' it were not in the winter season. Another way of weakening the menstruum is, by diluting or lessening its tenacity. Of this we have an instance in the magisteries of jalap, benzoin, and of several other resinous and gummy bodies, dissolved in spirit of wine. For by the affusion of common water, the menstruum being too much diluted, is not able to keep those particles in the state of fluidity, but must suffer them to subside, or make some parts emerge. Examples, also, of this kind, are



are afforded us by the common preparation of *Mercurius Vita*. For, tho' in oil of antimony, made by rectifying its butter, the saline particles are so numerous, and keep so close to one another, as to be able to sustain the antimonial corpuscles they carried over with them in distillation, and retain them, with themselves, in the form of a liquor; yet when by the plentiful affusion of water, those sustaining particles are separated, and removed to a distance from each other; the antimonial corpuscles, and the mercurial, if any such there were, being of a ponderous nature, will easily subside into that emetic powder, which when wash'd, is called *Mercurius Vita*.

But here, to shew how much precipitations depend upon the mechanical textures of bodies; tho' not only in the last examples, but in many others, the affusion of water, by diluting the salts and weakening the menstruum, makes the metal, or other dissolved body fall to the bottom; yet if the saline particles of the solvent, and those of the body be fitted for so strict an union, that the corpuscles resulting from their coalitions, will not so easily be separated by the particles of water, as suffer themselves to be carried up and down with them; they will not be precipitated out of the weakened solution, but still continue a part of it; as I have tried with some solution of silver and gold, made in acid menstrooms; but much more satisfactorily in solutions of copper, made in the urinous spirit of sal-armoniac. For tho' that blue solution were diluted with many thousand times the weight of the dissolved metal; yet its swimming corpuscles appear'd, by their colour, to be manifestly dispersed thro' the whole liquor.

Another way whereby precipitations of bodies may be produced, by weakening the menstruum, is to lessen the proportion of the solvent to the dissolved substance, without evaporation. Now, considering, that water will not dissolve salts indefinitely, but when it has received its due proportion, dissolve no more, and if they be put into it, let them fall to the bottom, and continue undissolved; and that if, when water is thus satiated, any of the liquor be evaporated, or otherwise wasted, it will, in proportion, let fall the salt it had already taken up; I concluded, that if I could add to water, any liquor, with which its particles would more readily associate than with those of salt, the depriving the solution of so many of its aqueous particles, would be equivalent to the evaporation of about as much water, as they, by being united, could compose. Wherefore, making a lixivium of distilled water, or clean rain-water, and of salt of tartar, so strong, that, if a grain more were added, it would lye undissolved at the bottom; I put a quantity of this lixivium into a slender cylindrical vessel, till it had therein reached to a proper height; then taking a sufficient quantity of most pure spirit of wine, I poured it upon the saline solution, and shaking the liquors well to-

X x x 2

gether,

PHYSICS. urther, to bring them to mix, I laid the tube in a quiet place; and afterwards found, that there was a considerable quantity of white salt of tartar fallen to the bottom of the vessel; which salt had been merely forsaken by the aqueous particles, that sustained it before, to pass into the spirit of wine, wherewith they were more disposed to associate. This I concluded, because having, before I poured on the spirit, made a mark on the glass, to shew how far the lixivium reached, I found, that after the precipitation, the lixivium, which remained yet strong enough to continue unmixed with the incumbent spirit, was sunk with its surface, considerably below the mark; the spirit of wine having gained in extent, what it lost in strength by receiving so many aqueous particles into it. I also made the like trial with dephlegmed spirit of wine, and as strong a brine, as I could procure from common salt dissolved without heat, in water; whereby I obtained a considerable proportion of finely-figured salt, which was let fall to the bottom. But this experiment, to be successful, requires greater care than the former. To confirm, and vary this way of precipitation, I made a clear solution of gum arabic in common water, and poured upon it a little high rectified spirit of wine, whereby there was made a large precipitation of a light, and purely white substance. And for farther confirmation, I dissolved a full proportion of myrrh in fair water, and into the filtered solution, which was transparent, but of an high-brown colour, dropped a large proportion of dephlegmed spirit of wine, which made a great precipitation of the gum. These instances seem to shew, that simple water is a real menstruum, which may have its dissolving, and sustaining virtue, weakened by the addition of liquors, much stronger than it.*

By insisting upon these several ways, whereby precipitations may be mechanically performed and accounted for, I would not be thought to deny, that there are any omitted. These were only the chief which

* Sir *Isaac Newton* speaks thus of precipitation. "When oil of tartar *per deliquium*," says he, "being poured into the solution of any metal, precipitates the metal, and makes it fall down to the bottom of the liquor in form of mud; does not this argue, that the acid particles are attracted more strongly by the salt of tartar, than by the metal; and by the stronger attraction go from the metal to the salt of tartar? And so when a solution of iron in *Aqua fortis*, dissolves the *Lapis Calaminaris*, and lets go the iron; or a solution of copper dissolves iron immersed in it, and

"lets go the copper; or a solution of silver dissolves copper, and lets go the silver; or a solution of mercury in *Aqua fortis* being poured upon iron, copper, tin, or lead, dissolves the metal, and lets go the mercury; does not this argue, that the acid particles of the *Aqua fortis* are attracted more strongly by the *Lapis Calaminaris*, than by iron, and more strongly by iron than by copper, and more strongly by copper than by silver, and more strongly by iron, copper, tin, and lead, than by mercury?" *Newton. Optic. p. 355.*

at present occur'd. And I shou'd be glad to have the subject consider'd as it deserves; for the doctrine and history of precipitations, well delivered, will be a thing of more extent and moment, than seems hitherto to have been imagined; since, not only several of the morbid changes in the blood, and other fluids of the human body, may thereby be the better understood, and prevented; but, also, in the practical part of mineralogy, many useful things may, probably, be performed by means of such a doctrine and history.





T H E MECHANICAL ORIGIN O F

Corrosivenefs and Corrosibility.

S E C T. I.

*The theory of
corrosivenefs.*

I Do not here design to treat of corrosivenefs, in their strict sense of the word, who ascribe this quality only to liquors, which are considerably acid, or sour, as *Aqua fortis*, spirit of salt, vinegar, juice of lemons, &c. but in a greater latitude, so as to make it almost equivalent to the dissolving power of liquors: and in this sense, the properties which seem most proper to render a liquor corrosive, are all of them mechanical.

And first, 'tis requisite, that a corrosive menstruum, shou'd abound with corpuscles not too big to get in at the pores of the body to be dissolved, nor yet so minute, as to pass thro' them; as the rays of light thro' glafs; or be unable, by reason of their great slenderness and flexibility, to disjoyn the parts they invade. Secondly, that these corpuscles be of a shape fit to insinuate themselves into the pores above-mentioned, in order to dissociate the solid parts. Thirdly, that they have a competent degree of solidity to disjoyn the particles of the body to be dissolved; which solidity of solvent particles is somewhat distinct from their bulk, as may appear by comparing a stalk of wheat, and a metalline wire of the same diameter. Fourthly, that the corpuscles of the menstruum, be such as are fit to separate the parts of the invaded body, either by their shape, minuteness, or fitness to have their action befriended by assisting causes; such as, first, the pressure of the atmosphere, which may impel them into the pores of bodies, not filled with a substance so resisting as common air:

air: as we see, that water will, by the prevalent pressure of the surrounding air or water, be raised to the height of some inches in capillary glass tubes; and in the pores of sponges, whose consistent parts yielding easier than the sides of glass-pipes, those pores will be enlarged, and consequently the sides disjoined, as appears by the dilatation, and swelling of the sponge: and secondly, the agitation, that the intruding corpuscles may be fitted to receive in those pores, by the transcurfion of some subtile ethereal matter; or by the numerous pulses of the swimming corpuscles of the menstruum itself; whereby, like so many little wedges, and levers, they may be enabled to force asunder the little parts, between which they insinuate. But to come to experiments.

1. It is obvious, that tho' the juice of grapes is sweet, whilst it retains the texture which belongs to it when new; yet after fermentation, it degenerates into vinegar: in which liquor, to a multitude of the more solid corpuscles of the must, their frequent and mutual attritions may be supposed to have given edges; and thus, perhaps, the confused agitation unsheathed some acid particles, which at first lay concealed in the must. Now, this liquor, that by the fore-mentioned mechanical changes is become vinegar, abounds with corpuscles, which, on account of their edges, and penetrative shape, will dissolve coral, crabs-eyes, some stones, *Lapis stellaris* in particular, as also minium, and even crude copper. And not only the distilled spirit of it will do these things more powerfully; but the saline particles, that usually remain after distillation, may, by being distilled, and cohobated *per se*, or by being skilfully united with the spirit, be brought to a menstruum, of no small efficacy in the dissolution of metalline bodies, too compact for the mere spirit itself to work upon. Vinegar may, also, be made of several other sweet things, and even of honey skilfully fermented with a small proportion of common water.

Confirm'd by
experiments.

2. Moreover, several dry woods, and other bodies, which pass for insipid, afford, by distillation, acid spirits, that will dissolve coral, pearls, &c. and also corrode some metals. So that the violent operation of the fire, which destroys what is call'd the form of the distill'd body, and works as a mechanical agent, produces an acid, corrosive menstruum.

3. 'Tis observed by refiners, that *Aqua fortis*, and *Aqua regis*, dissolve metals, much more speedily, when an external heat gives their intestine motions a new degree of velocity, which is but a mechanical thing; yet this additional agitation is that, without which some menstrooms will not sensibly operate on bodies at all; as we have tryed by keeping quick-silver in three or four times its weight of oil of vitriol, whereby the mercury was not dissolved or corroded, tho' kept for a long time; but when the oil of vitriol was excited by a convenient heat, it corroded the mercury into a fine white calx, which by the
affusion

PHYSICS. affusion of fair water, would be presently turned into a precipitate, of the colour and nature of a turbith. And having dissolved, in a weak spirit of salt, a fourth part of its weight of fine crystals of nitre, we found, that it would not, in the cold, dissolve leaf-gold; but when the menstruum was a little heated by the fire, that solution was readily made. In some cases also, tho' the external heat be small, yet there may happen another brisk one, and greatly assist in the dissolution of a body; as for instance, of quick-silver in *Aqua fortis*. For it is not strange to find, that when a full proportion of that fluid metal has been taken, the solution, tho' at first altogether liquid, and as to sense uniform, comes to have, after a while, a large quantity of coagulated matter at the bottom; of which the cause may be, that in the very act of corrosion, there is excited an intense degree of heat, which giving a new degree of agitation to the menstruum, makes it dissolve much more, than afterwards, when the conflict is over, it is able to keep up.

4. We have observed also, that agitation, in some cases, so much promotes the solutive power of saline bodies, that tho' they be not reduc'd to that subtilty of parts, to which a strong distillation brings them; yet they may, in their grosser form, have the power to work on metals. By barely boiling some solutions, of salts of a convenient structure, as nitre, sal-armoniac, &c. with leaf-gold, silver, &c. we have corroded these metals, and can dissolve some others. And by boiling crude copper filings with sublimate, and common water, we were able, in no long time, to make a solution of the metal.

5. Sometimes, likewise, so languid an agitation, as that which seems but sufficient to keep a liquor in the state of fluidity, may suffice to give a dry body a corroding power, which it could not otherwise exercise; as in the way of writing upon the blade of a knife with corrosive sublimate, wetted with common water. For after a while, all the parts of the blade, that should not be fretted, being protected by a covering of wax, the sublimate will corrode, only where way has been made for it in the wax by a bodkin; and the letters will be the more or less deeply etch'd, according to the time the sublimate is suffered to lye on: and if we only intend a legible impression, a few minutes may serve the turn.

6. Besides, several bodies, found unable to dissolve others, in moderate-degrees of heat, may yet, by intense degrees, be made fit solvents for them. Having a distilled liquor, which was rather sweet to the taste, than acid; I in vain try'd to make it work on pearls, in a more than ordinarily warm digestion; yet the glass being for many hours kept in such an heat of sand, as made the liquor boil, we had a thorough dissolution. And tho' the solvents of crude gold, are generally distilled acid liquors; yet alcalizate bodies, without the help of any liquor, will be enabled, by a melting fire, in no long time, to penetrate, and tear asunder the parts, even of crude gold;

so

so that it may afterwards be easily taken up in liquors, which are not acid, or even by water itself.

7. And tho' pure salt petre, when dissolved in water, is not observed to be a fit menstruum to dissolve some metals, or so much as coral itself; yet when by a convenient distillation, its parts are split, and by attrition, or other mechanical ways, reduced to the shapes of acid, and alkalizate salts; it then affords two sorts of menstrooms of very differing natures; which, between them, dissolve a great number and variety of bodies; as the spirit of nitre, without addition, is a solvent for most metals, viz. silver, mercury, copper, lead, &c. and also several mineral bodies, as tin-glass, spelter, *Lapis Calaminaris*, &c. and the fixed salt of nitre operates upon sulphureous minerals, such as common sulphur, antimony, &c.

8. By the preceding trials, it has appeared, that the increase of motion in the more penetrating corpuscles of a liquor, contributes much to its solutive power; I shall now add, that the shape, and size, which are mechanical properties, and sometimes also the solidity of the same corpuscles, eminently concur to qualify a liquor for dissolving a particular body. And of this, some of the more familiar practices of chymists may supply us with instances. For there is no account so probable, as may be given upon this supposition, why *Aqua fortis*, which will dissolve silver, without meddling with gold, should, by the addition of a fourth part of its weight of sal-armoniac, be turned into *Aqua regis*, which, without touching silver, will dissolve gold. But there is no necessity to have recourse to so gross and compounded a body, as sal-armoniac, to enable *Aqua fortis* to dissolve gold: for the spirit of common salt alone, being mixed in a due proportion, will suffice for that purpose. Which, by the way, shews, that the volatile salt of urine and foot, which concur to make sal-armoniac, are not necessary to the dissolution of gold; for which a solvent may also be made with *Aqua fortis*, and crude sea-salt. Nay, the mechanical affections of a menstruum may have such an interest in its solutive power, that even mineral, or metalline corpuscles, may become useful ingredients of it, tho' perhaps it be a distilled liquor; as might be illustrated by the operations of some compounded solvents, such as is the oil of antimony, made by repeated rectifications of what chymists call its butter, which greatly abounds in an antimonial substance.

9. But to shew, that a smaller change than one would imagine, of the bulk, shape, or solidity of the corpuscles of a menstruum, may fit it to dissolve a body, it would not work on before; we find not, that our spirit of salt, here in *England*, will at all dissolve crude gold; but by putting some leaf-gold into a convenient quantity of good spirit of salt, when we had drop'd in spirit of nitre, till the mixture was just able, in a moderate heat, to dissolve the gold, we found, that we had been obliged to employ only twelve drops of

the latter liquor, to an ounce of the former; so that supposing each of these drops to weigh a grain, the fortieth part of spirit of nitre being added, served to turn the spirit of salt into a kind of *Aqua regis*. But to know the proportion more exactly, we weighed six other drops of the same spirit of salt, and found them not fully to amount to three grains and an half: whence it appeared, that we added but about a seventieth part of the nitrous spirit, to that of salt.

10. The experiments hitherto recited, relate chiefly to the production of corrosive menstrooms; I shall now give an account of two experiments, which I made, manifestly to lessen, or quite destroy corrosiveness in liquors very conspicuous for that quality. One of the corrosive menstrooms yet known, is oil of vitriol, which will fret several metals, minerals, and a great number and variety of animal and vegetable bodies to pieces; yet if, for a while, you digest with it, an equal weight of highly rectified spirit of wine, and afterwards distil the mixtures very warily, you may obtain much of a liquor not corrosive at all; and the remaining substance will be reduced partly into a liquor, which, tho' acid, is not more so, than one part of good oil of vitriol will render ten times as much common water, by being well mixed with it; and partly into a dry substance, which hath scarce any taste at all, much less a corrosive one.

11. And tho' *Aqua fortis* be the most generally employed of corrosive menstrooms; yet to shew how much the power of corroding may be taken away by changing the mechanical texture of a menstruum, without seeming to destroy the fretting salts; I took equal parts of good *Aqua fortis*, and highly dephlegmed spirit of wine; and having mixed them warily, by degrees, we united them, by two or three distillations of the whole mixture; which we afterwards found not to have the least fretting taste, and to be so deprived of its corrosive nature, that it would not work upon silver, tho' by precipitation, or otherwise, reduced to very small parts; nay, it would scarce sensibly work, in a long time, on filings of copper, or upon other bodies, which mere vinegar, or perhaps rhenish wine will corrode. And with another spirit, not urinous, and afterwards with spirit of wine, we shewed a more surprizing instance of the power of destroying the corrosiveness of a menstruum. For, having put a piece of copper-plate into one ounce of *Aqua fortis*; when the liquor was eagerly working upon the metal, I caused an ounce of the pure spirit of wine, to be poured upon the agitated mixture; whose efferverescence, at the first instant, seemed to be much increased; but it was presently after checked, and the menstruum being speedily disarmed of its corrosiveness, the remaining copper was left undissolved at the bottom. Nor are these the only acid menstrooms, which I have, in this way, corrected: I applied it also to others, as spirit of nitre, and even *Aqua regis* itself; but it has not an equal operation upon all, and the least upon spirit of salt;

salt; as on the other side, it succeeds to greater satisfaction upon strong spirit of nitre.

Most of the chymists pretend, that the solutions of bodies are performed by a certain cognation and sympathy between the menstruum, and the body whereon it is to operate: and indeed, in several instances, there is, as it were, a relation between the menstruum and the body to be dissolved; as when sulphur is dissolved by oils, whether express'd or distilled: yet, as the opinion is generally proposed, I cannot acquiesce in it; because there are various solutions, and other phenomena, where it will not take place; and because, even in those instances, wherein it is thought most applicable, the effect seems to depend upon mechanical principles.

12. And first, it will be difficult to shew, what relation there is between sal-gem, antimony, iron, zink, bread, camphire, *Lapis Calaminaris*, flesh of several kinds, oyster-shells, chalk, and quick-lime; some of which belong to the vegetable, some to the mineral, and some to the animal kingdom; yet all of these, and several others may, even without the assistance of external heat, be dissolved or corroded by one single mineral menstruum, oil of vitriol.

13. I observe also, that a dissolution may be made of the same body by menstrooms, to which the chymists attribute mutual antipathy, and which, therefore, are not likely to sympathize with the same third body: thus I found, that both *Aqua fortis*, and spirit of wine, upon whose mixture there ensues a conflict, with great effervescence, will each of them a-part, readily dissolve crude zink, as also the filings of copper. Pure spirit of wine, and oil of vitriol, as great a difference as there is between them in many respects, will each of them dissolve camphire: and to these might be added other instances of the like nature.

14. As to what is commonly said, that oils dissolve sulphur, and saline menstrea metals, by reason of their similitude; I answer, that where there is any such similitude, it may very probably be ascribed not so much to the essential forms of the bodies, that are to work on each other, or to their salt, sulphur, or mercury; but to the congruity between the pores and figures of the menstruum, and the body dissolved by it; and to some other mechanical properties of them. Thus silver will not only be dissolved by nitre, which is reckon'd a salt, but will amalgamate with quick-silver, and also, by the operation of brimstone, be easily incorporated with that mineral, which chymists account of so oleaginous a nature, and insoluble in *Aqua fortis*.

15. And as for those dissolutions, which are made with oily and inflammable menstrooms, of common sulphur, and the other like bodies; they do not plead for them so clearly, as chymists imagine. For if such menstrooms operate, upon account of their sulphureous nature; whence is it, that highly rectified spirit of wine will not dissolve even the

PHYSICS.

flowers of brimstone, which essential, as well as express'd oils, easily take up? And this spirit of wine, itself will immediately do, if by the help of an alkali, the texture of the brimstone be altered; tho' the only thing added to the sulphur, being an incombustible substance, is nothing near of so sulphureous a nature as the flowers, and need have no relation, upon account of its origin with spirit of wine, as salt of tartar has; since I have tried, that fixed nitre will do the same.

16. Salt-petre, being looked upon by chymists, as a very inflammable body, ought, according to them, to be of a very sulphureous nature; yet we find, that it is not readily dissolved in chymical oils, but in water. Chymists tell us, that the solutions of alkalies, such as salt of tartar, or of pot-ashes, in common oils, proceed from the great similitude between them; but I demand, whence it happens, that salt of tartar will, by boiling, be dissolved in the express'd oil of almonds, or of olives, and be reduced with it to a soapy body; tho' with the essential oil of juniper or aniseed, &c. where, what they call the sulphur, is made pure and penetrant, you may boil salt of tartar twenty times as long, without making any soap of them, or perhaps any sensible solution of the alkali? And chymists know, how unsuccessfully it is attempted to dissolve pure salt of tartar, in pure spirit of wine. I will not urge, that tho' the most conspicuous mark of sulphur be inflammability, and is, in an eminent degree, to be found in oil, as well as sulphur; yet an alkali, and water, which are neither singly, nor when united, inflammable, will dissolve common sulphur.

17. But to make it probable, against the chymists, that the solution of sulphur in express'd oils, depends upon something, besides the abundance of the second principle in both the bodies, many chymical writers themselves reckon *Aqua regis*, which is plainly a saline menstruum, and dissolves copper, iron, coral, &c. like acid liquors, among the solvents of sulphur; and by that power, amongst other things, distinguish it from *Aqua fortis*. On the other side, if there be a congruity between an express'd oil, and another body, tho' it be such, as by its being easily dissolved in acid salts, chymists should pronounce of a saline nature, an express'd oil will readily work upon it; as I have tried by digesting copper filings, with oil of sweet almonds, which took up, like a corrosive liquor, so much of the metal, as to be deeply coloured thereby. Nay, even with milk I have found a kind of dissolution made of crude copper; as appeared by the greenish blue colour the filings acquired, when they had been well drenched in it, and left for a certain time in the vessel, where the air had very free access to them.

18. Besides the argument drawn from *Aqua regis*, it may be proper to urge another of the same kind against the generality of the followers of *Helmont* and *Paracelsus*, who allow of the operations of the alkahest. It is affirmed, that this irresistible menstruum will dissolve all tangible bodies into insipid water; but then as, on the other side,
it

it will be very hard to conceive, how a particular menstruum, which is determined to be either acid, lixivate, or urinous, &c. should be able to dissolve so great a variety of bodies, of differing, and perhaps contrary natures; so, on the other, if the alkahest be not a particular menstruum, it greatly discredits the opinion of the chymists, who will have some bodies dissolvable only by acids, others by fixed alkalies, and others again by volatile salts; since a menstruum, which is neither acid, lixivate, nor urinous, is able to dissolve bodies, in some of which, one, and in others, another of those principles is predominant. So that if a liquor be conveniently qualified, it is not necessary, it should be either acid, to dissolve pearl, or coral, or alkali-
zate, to dissolve sulphur.

19. If we duly reflect upon the usual process in making *Mercurius dulcis*, we shall find it very favourable to our hypothesis. For tho' we have already shewn, that common sublimate, made of mercury, is a highly corrosive body; yet if it be well ground, with near an equal weight of quick-silver, and be a few times sublimed, it will become so mild, as not to taste sharp upon the tongue; whence the chymists call it *Mercurius dulcis*; yet this dulcification seems to be performed in a mechanical way. For, most part of the salts, which made the sublimate so corrosive, abide in the *Mercurius dulcis*; but being compounded with more quick-silver, they are diluted by it, and acquire a new texture, which renders them unfit to operate, as they did before, when the fretting salts were not joyned with a sufficient quantity of the mercury, to restrain their corrosive activity. And this it may do either by sheathing, or rubbing and grinding off their sharp points, or cutting edges; as by some such mechanical change, fretting salts either quite lose their sharpness, as alkalies, whilst they are imbedded with sand in common glass; or greatly abate in their corrosive acidity, as oil of vitriol, when, with steel, it composes *Vitriolum Martis*; or are else transmuted, or disguised, by conjunction with some corroded bodies of a peculiar texture, as when *Aqua fortis* makes, with silver, an extremely bitter salt or vitriol; and with lead, one which is positively sweet, almost like common *Saccharum Saturni*.

20. And to shew how much the efficacy of a menstruum may depend, even upon slight mechanical circumstances; I put upon lead a large quantity of well rectified *Aqua fortis*, in which the metal continued undissolved; tho', if the chymists say true, that the dissolving power of the menstruum consists only in the acid salts, with which it abounds, it seems naturally to follow, that the more of them are contain'd in a determinate quantity of the liquor, the more able it shou'd be to dissolve metalline bodies. And in effect we see, that if corrosive men-
struums be not sufficiently dephlegmed, they will not work on several of them. Conjecturing, however, that the saline particles, which swam in our *Aqua fortis*, might be more thronged together, than was convenient for a body of such a texture of saline parts; I diluted the
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PHYSICS.

menstruum with fair water, upon which the desired fitness betwixt the agent and the patient ensued; when, the liquor quickly began to fall upon the metal, and dissolved it. And thus silver, which, I found, would not dissolve in very strong *Aqua fortis*, was readily fallen upon by that menstruum, when I had weakened it with common water.

S E C T. II.

The theory of
corrosibility.

CORROSIBILITY being the correspondent quality to corrosiveness, the distinction already made of the former, will shew in what sense I use the latter. And this corrosibility of bodies, as well as their corrosiveness, is a relative thing; since gold, for instance, will not be dissolved by *Aqua fortis*, but will by *Aqua regis*; whilst silver cannot be dissolved by the latter of these menstrooms, but may by the former. And this relative property seems to consist chiefly in three requisites, all which depend upon mechanical principles.

The first is, that the body to be corroded have pores of such a magnitude and figure, that the corpuscles of the solvent may enter them, and agitate the solid parts, which inclose them: for want of this condition, glass is penetrated in a multitude of places, but not dissipated, by the incident rays of light, which permeate its pores without any considerable resistance. And tho' the interstices of a body were less minute, and capable of letting in some grosser corpuscles; yet if these, for want of solidity or rigidness, were too flexible, or of a figure unsuitable to that of the pores they should enter, a dissolution would not ensue; as it happens, when pure spirit of wine is, in the cold, put upon salt of tartar, or *Aqua fortis* upon powder of sulphur.

The second qualification is, that its consistent corpuscles be of such a bulk and solidity, as does not render them incapable of being disjoined by the action of the insinuating corpuscles of the menstruum. Agreeable to this, and the former observation, is the practice of chymists, who, when they would have a body wrought upon by a menstruum, otherwise too weak for it in its crude state, dispose it to receive the action of the solvent by previously opening it, that is, by enlarging the pores, making a comminution of the corpuscles, or weakening their cohesion. Thus, several bodies are brought, by fit preparations, to be resolvable in liquors, which would not work on them before. Thus, lime-stone by calcination becomes, in part, dissoluble in water; and some metalline calces will be wrought upon by solvents, that would not touch the crude metal. Thus, tho' crude tartar is very slowly dissoluble in cold water, yet when burnt, it may be presently dissolved in that liquor. And thus, tho' the filings of silver will

will not be at all dissolved by common water, or spirit of wine, yet if, by the interposition of the saline particles of *Aqua fortis*, the corpuscles be so disjoined, and suffer such a comminution, as they do in crystals of silver; the metal thus prepared, will easily dissolve, not only in water, but in well rectified spirit of wine. And the like solubility I have found in the crystals of lead made with spirit of verdigrease, or good distilled vinegar, and in those of copper made with *Aqua fortis*.

The last disposition to corrosibility consists in such a cohesion of the parts, as is not too strong to be superable by the action of the menstruum. This condition, tho' of kin to the former, is somewhat different from it; since a body may consist of parts, either bulky, or solid, which yet may touch one another in such small portions of their surfaces, as to be much more easily dissociable, than the minute or less solid parts of another body, whose contact is more full and close, and consequently their cohesion more strict; so that the corrosibility of a body is but a mechanical relation, resulting from the mechanical properties and contexture of its parts, as they intercept pores of such sizes and figures, as fit them to those of the corpuscles of the menstruum, which enter between and disjoin them. But to confirm this doctrine by a few experiments.

1. If we put highly rectified spirit of wine upon sulphur, or its flowers, the liquor will lye quietly thereon, without making any visible solution; and if such spirit were put on very dry salt of tartar, the salt would lye undissolved at the bottom; yet if the sulphur be first gently melted, and the salt of tartar, by degrees, put to it, and mixed therewith; as there results a new texture, discoverable by the new colour, so there will arise a disposition to be dissolved, that was not before in either of the ingredients; whence, tho' the mixture be kept till quite cold, or long after, provided it be secured from the air, the spirit of wine, being put to it, will thence acquire a yellow tincture in a minute; and in less than half a quarter of an hour, a red one; being richly impregnated with sulphureous particles, discoverable by the smell, taste, and several operations.

Confirm'd by experiments.

2. Spirit of salt will not dissolve crude mercury in the cold; and I once kept them, for a considerable time, in no small heat, without finding any solution. But if mercury be precipitated *per se*, that is, reduced to a red powder without addition, by the mere operation of the fire; the texture will be so changed, that spirit of salt will readily dissolve it.

3. And this experiment is the more remarkable; because, tho' oil of vitriol will, in a great heat, corrode quick-silver; yet I kept a precipitate *per se*, for several hours, in a considerable degree of heat, without finding it to be dissolved, or corroded by the menstruum: but, having put another parcel of the same mercurial powder into cold *Aqua fortis*, or spirit of nitre, a speedy dissolution ensued. And that this disposition to be dissolved by spirit of salt, which mercury ac-

quires

PHYSICS.

quires by being turned into a precipitate *per se*, is not merely the effect of the operation of the fire upon it, but of some change of texture, produced by that operation, may be argued from hence, that, tho' spirit of salt be a very proper menstruum, to dissolve iron, or steel; yet when that metal is reduced to a crocus, by the action of the fire, it leaves in the bottom of the glass, a considerable part scarce sensibly altered; so that the menstruum has seemed rather to have extracted a tincture, than to have made an ordinary solution; for the colour of it was a high yellow or reddish; whilst iron, dissolv'd in spirit of salt, affords a green solution. Whether, by repeated operations with fresh menstruum, farther dissolutions might in time be made, I will not say; it may suffice for our present purpose, that iron, by the operation of the fire, acquired not, as mercury had done, a facility, but a great indisposition to be dissolved by spirit of salt. We varied this experiment, by employing, instead of spirit of salt, strong oil of vitriol, which, being poured on a little *Crocus Martis*, made *per se*, did not, as that menstruum usually does upon filings of crude iron, readily fall upon the powder, with froth and noise, but rested for several hours calmly upon it, without producing any sensible warmth.

4. And it agrees very well with our doctrine, about the dependance of the corrosibility of bodies upon their texture, that from several of them, whilst they are in conjunction with others, there result masses, easily dissoluble in liquors, wherein a great part of the matter, if separated from the rest, would not be at all dissolved. Thus, common vitriol is easily dissolved in mere water; but if skilfully calcined, it will yield near half its first weight of insipid colcothar, which is soluble, neither in water, in *Aqua fortis*, or *Aqua regis*; tho' sometimes these will colour themselves upon it. We see, likewise, that simple water will, by boiling it with harts-horn, dissolve and make a jelly thereof; and yet, when calcined, common water is no longer a fit solvent for it, nor even oil of vitriol a thorough one.

5. I shall recommend to the followers of *Helmont*, an experiment of his, which seems to suit with the doctrine proposed. He tells us, that if, by a certain subtile menstruum, quick-silver be divested of its external sulphur, as he terms it, all the rest of the fluid metal, which he styles the kernel of mercury, will be no longer corrosible by it. So that, upon this supposition, tho' common quick-silver be so suited to *Aqua fortis*, that the same quantity of that will dissolve more of it, than of any other metal; yet, if by the deprivation of some portion of it, the latent texture of the metal be altered, tho' not the visible appearance, the body, which before was so easily dissolved by *Aqua fortis*, ceases to be at all dissoluble by it.

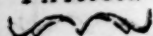
6. As for those chymists, who credit the strange things affirmed of the alkahest; we may urge them with what is delivered by *Helmont*, where he asserts, that all solid bodies, as stones, minerals, and metals themselves, by having this liquor duly abstracted, or distilled off from them,

them, may be changed into salt, of equal weight to the respective bodies, whereon the menstruum was put. So that, supposing the alkaleft to be totally abstracted, what other change, than of texture, can be reasonably imagined to have been made in the transmuted bodies? Yet several of them, as flints, rubies, sapphires, gold, silver, &c. which were insoluble before; some of them in any known menstruums, and others in any but corrosive liquors; become capable of being dissolved in common water.

7. It is a remarkable phenomenon, and confirms our opinion, about the interest of mechanical principles in the corrosive power of menstruums, and the corrosibility of bodies, that is produced in the following experiment. If we put large grains of sea-salt into common water, they will be dissolved calmly therein, without any appearance of conflict; but if such grains of salt be put into good oil of vitriol, that liquor will fall furiously upon them, and produce, for a long while, an hissing noise with fumes, and numerous bubbles, as if a potent menstruum were corroding some stubborn metal.

8. And tho' *Aqua fortis*, or *Aqua regis* poured upon filings of copper, will work upon them with much noise and ebullition, I have tryed that good spirit of sal-armoniac, or of urine, being put upon the like filings, and left there, without stopping the glass, will quickly begin to work on them, and quietly dissolve them, almost as water dissolves sugar. And even with oil of turpentine, I have dissolved crude copper; and the experiment seemed to favour our conjecture the more, because having made it several times, it appeared, that the common unrectified oil would perform the solution much quicker, than that which was purified by rectification; which, tho' more subtile, and penetrating, was, it seems, on that account, less fit to dissolve the metal, than the grosser oil, whose particles might be more solid, or more advantageously shaped, or on some other mechanical account better qualified for the purpose.

9. Dissolve good silver in *Aqua fortis*, and precipitate it with a sufficient quantity of spirit of salt; then having wash'd the calx, which will be very white, with common water, and dried it well, melt it, with a moderate fire, into a fusible mass, which will be very much of the nature with what the chymists call *Cornu Luna*, which they make by precipitating dissolved silver, with a bare solution of salt, made in common water. And tho' spirit of salt, and silver dissolv'd in *Aqua fortis*, will each of them a part, readily unite with simple water, our *Luna Cornea* will not, but is so indisposed to dissolution, that I have kept some long in digestion, with *Aqua fortis*, and some in *Aqua regis*, and in no faint degree of heat, without being able to dissolve it like a metal; the menstrua having, indeed, tinged themselves upon it, but left the composition undissolved at the bottom.



T H E

MECHANICAL PRODUCTION

O F

TASTES, and ODOURS.

S E C T. I.

The mechanical cause of tastes.

According to my notion of tastes, they depend upon the magnitude, figure, and motion of the sapid corpuscles, considered, either separately, and as the properties of single and very minute particles of matter; or else in a state of conjunction, as two or more of these properties, and the particles they belong to, may be combined or associated, either amongst themselves, or with others, which were not sapid before. And as these coalitions, and other associations, come to be diversified; so the tastes resulting from them, will be altered or destroyed. By taste, considered as belonging to the object, I mean that quality, or whatever else it be, which enables a body by its operation to produce in us the sensation, we call taste. That this quality, or whatever else it be, which makes or denominates an object sapid, may so depend upon the shape, size, motion, and other mechanical affections of the small parts of the body tasted, and result from the association of two or more of them, not excluding their congruity, or incongruity to the organs of tasting, may be made probable by the following instances.

A body, almost insipid, divided into two bodies of very strong, and very differing tastes.

1. It is observed, that salt-petre refined, and freed from the sea-salt that is mixed with it, rather cools the tongue, than makes any sapid impression on it, baking a very faint and languid bitterishness, which seems to be its proper taste; yet being distilled, by the way of inflammation, or by the help of a tasteless addition, it affords both a spirit, which is extremely sharp upon the tongue, and will dissolve several metals, and

and a fixed salt, which is, likewise, very strongly tasted, but altogether different from that of the spirit; and, accordingly, this salt will dissolve several compact bodies, that the other will not touch; and precipitate various metals, and other concretes out of those solutions, which have been made of them by the spirit.

2. If upon the liquor of fixed nitre, made *per deliquium*, you warily drop just enough good spirit of nitre, to satiate the alkali, you may, by a gentle evaporation, and sometimes without it, obtain crystals, which will have, upon the tongue, neither a sharp, nor an alkalizate taste, but the faint, and scarce sensible bitterness, that belongs to pure salt-petre. The like production of salt-petre we have sometimes had in far less time, and sometimes indeed in a trice, by substituting, instead of the fixed salt of nitre, the saline parts of good pot-ashes, carefully freed, by solution and filtration, from the earthy and feculent ones.

Two bodies, the one highly acid, and the other alkalizate, produce a third almost insipid.

Now the phenomena of these two experiments may seem explicable from the new magnitudes, and figures of the particles, which the fire, by breaking, or forcibly rubbing them one against the other, or also against the corpuscles of the addition, may be presumed to give them; as if, for example, allowing the corpuscles of nitre to be little prisms, whose angles and ends are too obtuse to make deep impressions on the tongue; if these little prisms be, by a violent heat, split, or otherwise broken, or forcibly made to grind one another, they may come to have parts so much smaller than before, and endowed with such sharp sides and angles, that, being dissolved and agitated by the saliva, which usually moistens the tongue, their smallness may give them free access to the pores of that organ; and the sharpness of their sides and points may fit them variously to stab and cut the nervous *Papille* of it, according to the grand diversities, as to shape and bulk, of the sapid particles. And this being granted, it seems farther conceivable, that, when the alkalizate and acid particles were put together in the fluid mixture, wherein they swam, many of them might, after a multitude of various jostlings, and excursions, meet with one another so luckily, as to re-compose little prisms, or convene into other bodies, almost like those, that made up the crystals of nitre, before it was exposed to the fire. Thus, tho' a prism of iron may have such a shape, as to be wholly unfit to pierce the skin; yet 'tis possible to cut it by transverse planes, reaching to the opposite bases or ends, so as to make wedges, which, by the sharpness of their angles may be fit to cleave wood, and cut the skin; and these wedges, being again put together after a requisite manner, may re-compose a prism, whose extremes shall be too blunt to serve the former purpose.

3. We very warily pour'd upon crystals of silver, dissolved in good *Aqua fortis*, or spirit of nitre, strong brine, made of common salt and water. The mixture of these being dried, and afterwards fused in a crucible, and kept a competent time in that state, affords a tough

An insipid mixture of bitter and salt bodies.

PHYSICS.

mass, called by the chymists *Luna cornea*, which being lick'd several times, will scarce be judged other than insipid; nor will it be easily brought to dissolve in much more piercing menstrua than our saliva.

An insipid mixture of sweet and salt bodies.

4. Take a strong solution of minium, made with good spirit of vinegar; or take *Saccharum Saturni*, dissolved in a convenient vehicle; and be very careful to put to it, by degrees, a just proportion of strong spirit of sal-armoniac, or the like urinous spirit, till the whole be precipitated; and if the two former tastes are not sufficiently destroyed thereby, the mixture, being dried and fluxed, as in the *Luna cornea*, will become insipid.

An insipid body and a sour one, make another more bitter than gall, or aloes.

5. Dissolve in strong spirit of nitre, or good *Aqua fortis*, as much pure silver, as the menstruum will take up; this solution being filtered has been often esteemed more bitter than gall, wormwood, aloes, &c. and if the superfluous moisture be abstracted, you may, by coagulation, obtain crystals of silver, that have been judged more strongly bitter than the solution. And that the corpuscles of these crystals should leave a far more lasting taste of themselves, than the most bitter bodies, will not seem strange, if we take notice how deep the particles of these crystals may pierce into the spongy organs of taste; since, if one does but touch the pulp, or nail of one's finger, first a little wetted, with the powder of such crystals, it will penetrate, and stick so fast there, that you cannot in a reasonable time get off the stain.

An insipid body, and a corrosive one made into a sweet substance.

6. Put purified *Aqua fortis*, or spirit of nitre, upon good minium, letting them work on one another in a gentle heat, till the liquor has dissolved its full proportion of the metal; when, if the ingredients be good, and the operation rightly performed, the menstruum will have a sweetness, like that of ordinary *Saccharum Saturni*. But if the minium be adulterated, as often it is; or the spirit of nitre, or *Aqua fortis* be mixed with spirit of common salt, or other unfit ingredients, the experiment will not succeed, as I have more than once observed.

Liquors corrosive enough to dissolve metals, obtain'd from the sweetest bodies.

7. If sugar be put into a large retort, and warily distilled, it will afford, among other things, a large quantity of a red spirit, which being slowly rectified, loses its colour, and comes over clear. The *Caput mortuum* of the sugar may be found either almost, or wholly insipid. And tho' the spirit will be of a very piercing taste, yet it will be very far from any kind of sweetness; and tho' that liquor be thought homogeneous, and to be one of the principles of the analyzed sugar, yet I found it to be a mixture of two spirits; with the one of which, besides bodies of a less close texture, I dissolv'd crude copper; as was easy to be seen by the deep and lovely colour of the solution. And to these four spirits, afforded by sugar itself, we have restored a kind of saccharine sweetness, by compounding them with the particles of so insipid a body as minium; part of which they will in digestion dissolve.

olve. A like spirit to that distilled from sugar, may be obtained from honey; but as it is apt to swell exceedingly, chymists do not distil it without sand, brick, or some other addition.

8. Put some fine crystals of silver into a good retort, and then distilling them in a sand-furnace, capable of giving them so strong a fire, as to drive away all the spirits from the silver, this, remaining behind, will, according to its metalline nature, be insipid, and the spirits, that are driven away from it, will unite in the receiver into an acid and corrosive menstruum.

9. As the following operation may help to discover the figures of the particles of dissolved metals, and other bodies; so it is very fit to shew, how much taste may be diversified by, and consequently depend upon texture; since a body, that hath no taste, may, in conjunction with sapid bodies, give them strong tastes, all differing from one another, and each of them from that, which the sapid bodies had before. Zink will be dissolved not only by *Aqua fortis*, *Aqua regis*, oil of vitriol, spirit of nitre, spirit of salt, and other mineral menstrooms, but also by vegetable spirits, as distilled vinegar; and by animal ones too, as spirit of sal-armoniac; tho' the one be acid, and the other urinous. And if the several solutions, which may be made of this mineral, by so many differing liquors, be compared, the number of their differing tastes, will suffice to shew that a variety of tastes is producible from one insipid body, by associating it with different menstrea.

10. The next experiment may pass for a converse of the foregoing; and as it serves, as well as that, to discover the structure of the minute parts of metalline and mineral bodies; so it may, better than that, serve to illustrate the doctrine of tastes; by shewing, that a single, simple body, endowed with a peculiar taste, may, by being compounded with others, each of them insipid of itself, produce a considerable number of differing tastes. More instruments than one might be used in this experiment; but of those which are known, and easily obtain'd, the most proper are spirit of nitre, and good *Aqua fortis*; which, with refined silver, make a solution bitter as gall; with lead, one of a saccharine sweetness; with that part of tin, they will keep dissolved, a taste very different from both the former, but not odious; with copper an abominable taste; and with mercury and iron, other kinds of bad tastes. Nor are metals the only mineral bodies they thus work upon: they also dissolve tin-glass, antimony, brass, emery, zink, &c. all which together make up no despicable number of differing tastes.

11. The next instance is still more proper for our purpose; because the corrosive menstruum is here neither mortified by fixed nor urinous salts, supposed to be of a contrary nature to it; nor yet disarmed by corroding of metals, or other solid bodies. The experiment being somewhat dangerous when made in great quantities, it may answer our

PHYSICS.

A body, bitter in the highest degree, divided into two substances, the one extremely sour, and the other perfectly insipid.

Variety of tastes produced in one insipid body, by associating it with different menstrooms.

Variety of tastes produced with one menstruum, by associating it with insipid bodies.

Two liquors, one highly corrosive, and the other very pungent, compose a body of a pleasant aromatic taste.

PHYSICS. end, to make in less, as follows. Take one ounce of strong spirit of nitre, or of very good *Aqua fortis*, and very gradually put to it another ounce of rectified spirit of wine. When these two liquors are well mixed, and grown cold again, distil them totally over together, to unite them exquisitely into one liquor; in which, if the operation hath been well performed, the corrosive particles of the salts will not only lose all their cutting acidity; but, by their new composition with the vinous spirit, the liquor acquires a vinous taste, which is very pleasing and aromatic.

The peculiar
tastes of natural
bodies,
imitated by
art.

12. Perhaps it will not be erroneous to conceive, that, whatever be the agent in reference to those tastes, which are said to be specific to this or that plant; yet that, on whole immediate account it is, or becomes of this or that nature, is a complication of mechanical properties, such as shape, size, &c. in the particles of the matter, which is said to be endowed with such a specific taste.

To illustrate this, I attempted to imitate the taste of some natural bodies by artificial ones; but found it not easy, before-hand, to know the success of such trials. Making some experiments to alter the sensible qualities of oil of vitriol, and spirit of wine, I obtained from them, among other things, a certain liquor, which, tho' at first pleasant, would, at a certain juncture of time, make one, who held it in his mouth, think it had been imbued with garlic. And a person famous for making good cyder, complained to me, that having, among other trials, put into a vessel full of juice of apples, a certain proportion of mustard-seed, in hopes it would make the cyder more sharp and spirituous, he found it smell so rank of garlic, that every body rejected it. I remember also, that by fermenting a certain proportion of *Semen Dauci* with ale, the liquor had a very pleasant relish of lemon-peel. But it seems much more considerable, that with an insipid metal, and a very corrosive menstruum, a taste may be compounded, so like a vegetable, as to deceive many. This may be done by dissolving gold, without any gross salt, in a mixture of *Aqua fortis*, and the spirit of salt, or even in common *Aqua regis*, made by dissolving sal-armoniac in *Aqua fortis*. For if the experiment be happily made, there will be obtain'd, either a solution, or a salt, whose austere taste very much resembles that of sloes, or unripe bullace. And this taste, with some little variety, I found in gold dissolved without any distilled liquor at all; and also, in gold, which by a peculiar menstruum I had volatilized. The next instance, I found to have been known to some ingenious ladies. But to make the experiment succeed very well, a due proportion is the principal circumstance, which is usually neglected. I cannot call to mind that which I found to succeed best, but the trial may be indifferently well made, after this manner. Take a pint of malaga or canary, and put into it a dram or two of good orrice roots, cut into thin slices, and let them infuse in the liquor for a convenient time, till you perceive it has gain'd

gain'd the desired tast and smell; then keep the thus perfumed wine exactly stopped in a cool place: by this means, I had a liquor, which, coloured with cochineal, was taken for good raspberry-wine. PHYSICS.

13. It will not perhaps be unacceptable to add a word or two, on this occasion, for their sakes, who think the maturation of fruit, and the changes of tastes, by which it is usually known, are the effect of the vegetable soul of the plant. For, after the fruit is gathered, and being no longer a part of the tree, ceases, according to the most common opinion, to be a part of the living plant, it belonged to; yet it is very possible, that some fruits may receive maturation, after they have been severed from the plants that bore them. Apples, pluck'd too soon, usually obtain a mellowness by lying in heaps; which seems to be a kind, or degree of maturation; and medlars, gathered whilst they are hard and harsh, afterwards become soft, and better tasted. 'Tis also asserted by several writers of the affairs of *India*, that the fruit, they call *Bananas*, is usually gathered green, and hung up in bunches, in the house, where they ripen by degrees, and have an advantageous change made both of their colour, and tast. And this experiment, an ancient acquaintance of mine assured me, he had himself lately tried, and found to be true, in *America*. And indeed I see not, why a convenient degree of warmth, whether external from the sun and fire, or internal from some degree of fermentation, or analogous intestine commotion, may not put the sapid corpuscles into motion, and cause them, by various and insensible transursions to rub against each other, and thereby make the little bodies more slender and thin, less rigid or cutting, than they were before; and by various motions bring the fruit they compose to a state, wherein it is of a more soft consistence, and abounds in corpuscles less harsh, and more pliable, than formerly, and better fitted to the pores of the organ of tast; and, in a word, make such a change in the constitution of the fruit, as we express by the name of maturity. And that such mechanical changes of texture may much alter the qualities, and among them, the tast of a fruit, is obvious in bruised cherries and apples, which, in the contused parts, soon come to look and tast otherwise than they did before. The possibility of this is also obvious from warden pears, gently roasted in embers. And I have seen in the country between *France* and *Savoy*, a sort of pears, which, being kept for some hours in a moderate heat, in a vessel exactly closed, with embers and ashes above and beneath them, will be reduced to a juicy substance, of a lovely red colour, and a very sweet luscious tast. Many other sorts of fruit, in different countries, if they were managed after the same way, would admit of as great alterations in point of tast. And that more stubborn salts, than those of vegetables, may have the sharpness of their tastes very much abated, by the bare internal action of one part upon the other, I have been induced to think, from observing, that by the help of insipid water, we may reduce sea-salt into a brine,

*Some changes
made of tastes
by maturation.*

PHYSICS.

brine, of so mild and peculiar a taste, that one would scarce suspect what it had been; or believe, that so great a change of a mineral body could be effected by so slight and intestine commotion as produced it. As to vegetable liquors, the production of new tastes upon the intestine commotions of the sapid parts, is obvious in the juice of grapes, which, from a sweet and spiritless liquor, acquires that pleasing pungency and briskness of taste, which belongs to wine; and afterwards degenerates into that acid and cutting taste, proper to vinegar; and all this from a change of constitution, made by the action of the parts themselves, one upon another, without the help of any external addition.

S E C T. II.

The mechanical production of odours.

A strong smell produced by two scentless bodies.

A strong scent produced by water in a body, which had none before.

Produced odours differing from that of any of the ingredients.

Since tastes and odours are usually treated of immediately after one another, I shall also consider these two qualities successively; because much of what is already said of tastes, being applicable to odours, will save the trouble of repetitions.

1. Grind good quick-lime and sal-armoniac well together, and holding your nose to the mixture, you will find an urinous smell, produced by the particles of the volatile salt, which will also make your eyes water.

2. If a large proportion of camphire be dissolved in oil of vitriol, the odour of the gum will be quite concealed in the mixture; but if you pour this mixture into a large quantity of fair water, the dissolved gum will immediately recover out of the menstruum, and smell perhaps more strongly than before.

3. Having cautiously mixed two parts of clear oil of turpentine, with one part of the oil of vitriol, the clear liquor, that came over, upon distillation of the mixture, instead of turpentine, smelt very strong of sulphur; so that once, approaching very hastily to the receiver, newly taken off from the retort, the sulphureous scent proved so strong, as almost to take away my breath. And farther, to shew the possibility of producing such odours upon the mixture of ingredients, as neither of them was a-part endowed with, we caused the substance, that remained behind in the retort, in the form of a thin extract, after one of these distillations, to be farther urged by a stronger fire, which forced most of it over, partly in the form of a thick oil, and partly in that of butter; both which we kept together in the same vial; their odour being neither that of oil of turpentine, nor of brimstone; but exceedingly like the distilled oil of bees-wax.

4. That

4. That the celerity, and other modifications of the motion of the effluvia of bodies, may not only diversify their odours, but so far produce them, as to render them perceptible by the sense, may be gathered from some common observations. Several bodies are not only inodorous when cold, but when considerably hot; and tho' they remain fixed in the fire, yet, having their parts put into a peculiar kind of agitation, they will presently grow manifestly odorous. Some very hard woods, acquire a strong smell by the motion they may be exposed to in a turner's lath, particularly the *Lignum Vita*; and some, whilst the operation lasts, afford an unexpected odour. Having inquired concerning the scent of beech-wood, whilst it is turning, I was informed, that it would emit well-scented effluvia; and it was affirmed to me by a workman, who had bought a great block of this wood, that when he came to turn it, there would issue out, not only a great scent, but such a peculiar fragrancly, that one, who knew not whence it proceeded, would have concluded he smelt roses.

PHYSICS.

The production of odours by local motion.

5. Take salt of tartar, and drop upon it either spirit of nitre, or a weak *Aqua fortis*, till all the effervescence ceases, and the liquor no longer works upon the alkali; and these, by a slow evaporation of the superfluous moisture, may be made to shoot into crystals, like those of nitre; which, after you have, by rubbing with a dried cloth, freed from loose adhering corpuscles, resemble salt-petre, both in other qualities, and in not being odorous; tho', if you distil them, or burn them on kindled coals, their fumes will quickly appear to abound with the fetid spirits, which make *Aqua fortis* so offensive to the smell.

A scented body, by mixing with an inodorous one, deprived of all its smell.

6. What I shall next propose, is performed at the same time, the eleventh experiment of tastes is made. For the liquor thereby produced, if it be well prepared, has not only a spicy tast, but also a kind of aromatic and pleasant smell. And I have of it now by me, which has, for some years, retained much of its former odour, tho' not so much of its tast.

A pleasant aromatic odour produced by putting a fetid body to another not sweet.

7. To a pound of *Spanish* wine, we put some ounces of oil of vitriol; then keeping them, for a reasonable time, in digestion, we obtained an odoriferous mixture. But this experiment is improved by that which follows.

A fragrant odour produced by two bodies, not well scented.

8. We took good oil of blue *Dantzick* vitriol, tho' the common will serve; and having put to it, by degrees, an equal weight of spirit of wine, totally inflammable, we digested them together for two, three, or four weeks, sometimes much longer, and then with better success; when we came to distil the mixture, we had a very fragrant spirit, which was sometimes so subtile, that, tho' distilled in a tall glass, with a gentle heat, it would pierce the lute, and fill the laboratory with a sensible perfume: whence we learn, both how much those spirituous and inflammable particles, which chymists call the vegetable sulphur of wine, may work on, and enoble a mineral

By the addition of an inodorous body, a pleasant and aromatic smell given to spirit of wine.

PHYSICS.

fulphur; and how much the new contextures made by digestion, may alter the odours of bodies, whether vegetable, or mineral. That also another constitution of the same matter, without any manifest addition or recess of particles, may exhibit a very differing smell, will appear by the following trial.

The fore-mentioned fragrant body, brought to smell like garlick.

9. I have more than once put the above-mentioned liquor into stopp'd glasses, whereof the one, and not the other, stood in a warm place, till, in process of time, I found that odoriferous liquor so to degenerate in point of scent, that one would have thought it had been strongly infected with garlick. The like unpleasant smell I observed in a certain oil, made of vegetable and mineral substances distilled together. And on this occasion, may be added an observation, which, tho' I shall not undertake it will always hold good; yet shews, that a body, which itself is not only inodorous, but very fixed, may, in some cases, have a great share in the phenomena of odours. We put, then, to good salt of tartar, several times its weight of the expressed juice of onions, and kept them in a light digestion for a day or two; when unstopping the vial, we found the former smell of the onions quite degenerated into a rank smell of garlick, as we judged, even when fresh juice of garlick was compared therewith.

The smell of musk produced with an inodorous body, and another not well scented.

10. By casting into spirit of vitriol, a large proportion of small pearls unbroken; the action of the acid menstruum upon them being moderated by its weakness, and by the intireness of the pearls, the dissolution would sometimes last for many hours; when, holding my nose, from time to time, to the open orifice of the glass, it was easy to perceive a pleasant musky smell, which others also took notice of. And I observed the like smell upon pearls, being dissolved not only in spirit of vinegar, but in another liquor, which had but a bad scent of its own.

Pleasant scents produced with fixed metals, and fetid or scentless bodies.

11. That gold is too fixed a body to emit any odour; and that *Aqua regis* has an odour, which is very strong and offensive, will be easily granted; yet *Aurum fulminans* being made by precipitating with the inodorous oil of tartar, the solution of the former in the latter, and this precipitate being to be farther treated, in order to another experiment, we fulminated it *per se* in a silver vessel, like that, but better contrived, which is described by *Glauber*: and among other phenomena of this operation, we observed, that when the fulmination was just made, the steams afforded by the metal, which had been fired, gave a delightful smell, not unlike that of musk. From which experiment, and the foregoing, we learn, that art, by lucky contextures, may imitate the odours, which are presumed to be natural and specific; and that mineral and vegetable substances may compound a smell, which is thought peculiar to animals. And as art sometimes imitates nature in the production of odours, (as may be confirmed by what is above related concerning counterfeit raspberry-wine; for those, who drank it, believed they did not only taste, but smelt

smelt the raspberry;) so sometimes nature seems to imitate herself, in giving like odours to bodies extremely differing. There is a certain seed, which, for the affinity of its odour to that perfume, they call the musk-seed; some of which being presented me from the *West-Indies*, I found it, whilst fresh, to have a fragrant suitableness to the name, that was given it. There is, also, a sort of rats in *Muscovy*, whose skins have a smell, which has procured them the name of musk-rats. And I have seen a certain sort of ducks, call'd musk-ducks; because at a certain season of the year, if they are chaf'd by violent motion, they will, under the wing, emit a musky, instead of a sweaty scent; which, upon trial, I found true. On the other side, I have known a certain wood, growing in the *Indies*, which, especially when the scent is excited by rubbing, smells so rankly, and so like human dung, that one would swear that were held under his nose.

Tho' the fire generally impresses a strong offensive smell, which chymists, therefore, call empyreumatical, upon the odorous bodies it works strongly on; yet the constitution of a substance may be such, that the new texture made of its parts, even by a violent fire, shall be fit to afford effluvia, rather agreeable to the organs of smelling, than any way offensive. Having distilled *Saccharum Saturni* in a retort, with a strong fire, I obtained, besides a piercing and empyreumatical liquor, which was driven over into the receiver, a large lump of *Caput mortuum* of a greyish colour, which, notwithstanding the strong impression it receiv'd from the fire, had a pleasing scent, and, when broken, smelt almost like a fine cake new baked, and broken whilst yet warm. And as the fire, notwithstanding the empyreuma it usually gives to almost all the bodies it burns, may yet confer a good smell on some of them, if they be fitted, upon such a contexture of their parts, to emit steams of such a nature; we observe in the musk-animal, that nature, in that cat, or rather deer, produces musk by such a change, as is in other animals, produces a putrefactive scent. So that, provided a due constitution of parts be introduced into a portion of matter, it may, on that account, be endowed with noble, and desirable scents, or other qualities; tho' that constitution were introduced by such unlikely means, as combustion or putrefaction. An eminent professor of mathematics affirmed to me, that chancing one day, with another mathematician, in the heat of summer, to pass by a large dunghil, which was then in *Lincolns-Inn-fields*; when they came within a certain distance of it, they were both surprized to find a very strong smell of musk; which each, for some time, was shy of taking notice of, for fear the other should have laughed at him; but when they came much nearer the dunghil, that pleasing smell was succeeded by a scent, proper to such a heap of excrements. And indeed, tho' the excrements of animals, and particularly their sweat, are usually fetid; yet, that this is not the nature of an excrement, but the constitutions usually belonging to them, which make them so, hath

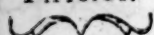
PHYSICS. seemed probable to me from some observations. For, not to mention what is related of *Alexander* the great, I knew a gentleman of a very happy temperature of body, whose sweat, upon a critical examination, I found to be fragrant; which was also confirmed by some learned men of my acquaintance, and particularly, by a physician, who lay with him. Tho' civet usually passes for a perfume; yet it seems to be but a clammy excrement of the animal that affords it, which is secreted into bags, provided by nature to receive it. And upon seeing several of these civet-cats; I observed, that a certain degree of remissness in the odorous atmosphere was requisite to make the smell fragrant. For when I have been near the cages, where many of them were kept together, or any great vessel, full of civet, the smell was rather rank, and offensive, than agreeable; but when I removed to a convenient distance, the steams being less crowded, and farther from their fountain, presented themselves as a perfume. And an ingenious lady shewed me an odd monkey, which had been presented her, as a rarity, by the *English* admiral; telling me, amongst other things, she had observed in it, that, being sick, he would seek for spiders, as his proper remedy; which when he had eaten, the alteration it made in him, would sometimes fill the room with a musky scent.

Good smells
heighten'd by
composition.

12. It is well known to perfumers, that amber-grease alone, tho' esteemed the best and richest perfume in the world, has but a very faint and scarce pleasant scent. And I have seen some hundreds of ounces together, newly brought from the *East-Indies*; but if I had not been before acquainted with the smell of amber-grease in the lump, my nostrils would scarce have made me suspect those lumps to have been any thing of kin to amber-grease. This amber-grease is, if I am rightly inform'd, a vegetable production, issuing out of the root of a tree, which always shoots its root towards the sea: and if it be planted where the stream sets to the shoar, 'twill be cast up to great advantage. But if a due proportion of musk, or even civet, be dextrously mixed with amber, the latent fragrancy, tho' it be thereby somewhat compounded, will be quickly called out, and exceedingly heightened. And indeed, it is not the great quantity of the richest ingredients, as amber-grease and musk, but the just proportion and skilful mixture of them, that makes the noblest, and most lasting perfume; of which I have had sufficient experience: so that with a far less quantity of musk and amber than perfumers themselves employ, we have had several perfumes, which, for fragrancy, were much prefer'd to those, where musk and amber-grease are so plentifully used. The best proportion for their mixture seems to be eight parts of amber-grease, two of musk, and one of civet; which quantities of ingredients, if skilfully and exactly mixed, will afford a good composition, wherewith to ennoble other materials, as benzoin, storax, &c. fit to make pastils, ointments for leather, &c. We may add, that upon account of the new texture, acquired by composition, some things, which are

are not fragrant themselves, may much heighten the fragrancy of odoriferous bodies. And for liquid perfumes, I remember it was the secret of some court-ladies, noted for curiosity in perfuming, to mix always a due proportion of wine-vinegar with the odoriferous ingredients. And to shew the power of mixture in improving odours, I shall mention a liquor of mine, which was very favourably spoken of by persons of quality, accustomed to choice perfumes. This liquor, tho' thought an elaborate preparation, and which, to recommend it to such whose critical palates can tast the very titles of things, I called essence of musk, is, indeed, a very plain simple preparation, which I thus make. I take any quantity of choice musk, without finely powdering it, and pour thereon about a finger's breadth of pure spirit of wine; I set these, in a glass closely stopped, in a quiet place to digest, without the help of any furnace, and after some days, or a few weeks, the spirit will, in the cold, have made a solution of the finest parts of the musk, and be thereby much tinged, but not of a red colour. This being decanted, I keep by itself as the richest of all; and pour like quantity of spirit on the remaining musk; and this, too, usually will, in the cold, tho' more slowly, draw a tincture, but fainter than the former, which being poured off, the remaining musk may be employed for inferior uses. I mention this preparation, because the first tincture, being smelt to by itself, has but a faint, and no very pleasing odour of musk; so that every one wou'd not expect there was musk in it; but if a single drop were mixed with a pint, or perhaps a quart of sack, the whole body of the wine would presently acquire a considerable musky scent, and be so richly perfumed, both in tast, and smell, as seemed strange to those, who knew the vast disproportion of the ingredients.





T H E
MECHANICAL ORIGIN
O F
HEAT and COLD.

S E C T. I.

*The origin of
cold mechanical.*

*To produce a
great degree
of coldness, at
any time of the
year.*

HEAT and cold being generally esteem'd the most active among qualities, from which several others are deducible, and by which many phenomena of nature are explicable; it will be proper to shew how they may either be mechanically produced or destroyed.

1. To produce a considerable degree of cold at any time of the year, without snow, ice, hail, wind, or nitre, take one pound of powdered sal-armoniac, and about three pounds of water; put the salt into the liquor either all together, if you would produce an intense short coldness; or at three or four times, if you desire, that the cold should rather last somewhat longer than be great; stir the powder in the liquor, with any thing that will not be injur'd by the fretting brine, to hasten the dissolution of the salt; upon the quickness of which very much depends the intenseness of the cold, that will ensue upon this experiment.

That a considerable degree of cold is here produced, will evidently appear to the touch; and if you make the experiment in a glass body, you may observe, that while the salt dissolves, the outside of the vessel will, as high as the mixture reaches, be bedewed with a multitude of little drops of water; as happens when mixtures of snow and salt, being put into glasses, the aqueous vapours that float in the air, and pass along the sides of the vessel, are, by the coldness thereof, condensed into water. And in our solution you may observe, if you wipe off the dew from any particular part of the outside of the vessel,

fel, whilst the solution goes vigorously on, it will quickly collect fresh dew, which will sometimes be large enough to run down the sides of the vessel. But the best and surest way of proving the coldness of the mixture, is by plunging into it a good sealed weather-glass, furnished with tinged spirit of wine: for the ball of this, being put into our frigorific mixture, the crimson liquor will suddenly descend much lower, than when it was kept either in the open air, or in common water, of the same temper with that, wherein the sal-armoniac was put to dissolve. And if you remove the glass out of our mixture into common water, the tinged spirit will ascend, according to the longer or shorter time, that it continued in the solution. And this hath succeeded, when, instead of removing it into common water, I removed it into water newly impregnated with salt-peter.

The duration of the cold produced by this experiment, depends on several circumstances, as, 1. The season of the year, and the present temper of the air; for in summer and hot weather, the cold will sooner decay and expire. 2. Upon the quantity of salt and water; for if both these be great, the effect will be more lasting and considerable. 3. We may, probably, add the goodness and fitness of the salt employed; for some trials have tempted me to suspect, that there may be a considerable disparity, as to their fitness to produce cold, betwixt parcels of salt that are, without scruple, taken for sal-armoniac. 4. The duration of the cold may be conceived to depend, also, upon the way of putting the salt into water. I have often tried, that when the tinged spirit subsided but slowly, or was at a stand, that by putting in, from time to time, two or three spoonfuls of fresh salt, and stirring the water, the spirit of wine would again descend much more swiftly. And if you would lengthen the experiment, let part of the sal-armoniac be but grossly beaten, that it may be the longer in dissolving. Whilst dewy drops are produced on the outside of the vessel, it's a sign that the cold within continues pretty strong; for when it ceases, these drops, especially in warm weather, will, by degrees, vanish. But a surer way of measuring the duration of the cold is, by removing, from time to time, the sealed weather-glass, out of the saline mixture into the same common water, with part of which it was made. I have in the spring-season, by a good weather-glass, found a sensible adventitious cold, made by a pound of sal-armoniac, to last about two or three hours.

March 27. In the sealed weather-glass, when first put into the water, the tinged spirit rested at $8\frac{5}{8}$ inches; being suffered to stay there a good while, and now and then stirred in the water, at length it descended a little beneath $7\frac{5}{8}$ inches; then the sal-armoniac being put in, within about a quarter of an hour, or a little more, it descended to $2\frac{1}{2}$ inches; but in half a quarter of an hour, it began manifestly to freeze the vapours and drops of water on the outside of the glass. And when the frigorific power was arrived at its height, I, several times,

PHYSICS. times, found, that water thinly placed on the outside, whilst the mixture within was nimbly stirred, would freeze in a quarter of a minute. At about $\frac{1}{4}$ of an hour after the infrigiding body was put in, the thermometer, that had been taken out a while before, and was yet risen but to the lowest freezing mark, being again put into the liquor, fell an inch below the mark. At about $2\frac{1}{2}$ hours from the first solution of the salt, I found the tinged liquor to be in the midst between the freezing marks, whereof there was one at $5\frac{1}{2}$ inches (at which height when the tincture rested, it would usually be a small frost abroad) and the other at $4\frac{1}{4}$ inches; the height to which strong and durable frosts had reduced the liquor in the winter. Within three hours after the beginning of the operation, I found not the crimson liquor higher than the upper freezing mark, just mentioned; after which, it continued to rise very slowly, for about an hour longer. The frigorific mixture, having been made in a glass body, with a large flattish bottom, a quantity of water, purposely spilt upon the table, was, by the operation of the mixture within the glass, made strongly to freeze the bottom of the cucurbite to the table; that stagnant liquor being turned into solid ice, which continued for a considerable while unthawed, and was, in some places, about the thickness of a half-crown piece.

At another time, during the same spring, the sealed weather-glass, which before it touched the common water, stood at $8\frac{1}{8}$ having been left there a considerable while, and once or twice agitated in the water, the tinged liquor sunk but to $7\frac{7}{8}$, or at the farthest $7\frac{1}{2}$; then the frigorific liquor being put into the water, with disadvantageous circumstances; in about half a quarter of an hour, the tinged liquor fell beneath $7\frac{1}{4}$; and the thermometer being taken out, and put in again, an hour after the water had been first cooled, subsided beneath five inches, and consequently was within $\frac{1}{4}$ inch of the mark of the strongly freezing weather.

The grand thing, likely to keep this experiment from being generally useful in cooling liquors, &c. is the dearness of sal-armoniac, which might come much cheaper, if, instead of fetching it from beyond sea, we made it at home; which may be easily done. And tho' a solution of sal-armoniac, being boiled up in earthen vessels, (glass ones being too chargeable) will lose the more subtle parts, and thereby impair the texture of the rest; yet I have found, that the dry salt, remaining in pipkins, being dissolved in a due proportion of water, would very considerably infrigide it.

March 29. The thermometer, that in the air was at $8\frac{7}{8}$ inches, being put into a large evaporating glass, filled with water, fell, (after it staid a pretty while, and had been agitated in the liquor) to eight inches; and then about half the salt, or less, that had been used twice before, and felt much less cold than the water, being put in, and stirred about, the tinged spirit subsided till it was fallen beneath
four

four inches, and then, having caused some water to be fresh pumped and brought in, tho' the solution were mixed with it, yet it presently made the spirit of wine manifestly to ascend in the instrument, much faster than one would have expected. To cool liquors with this mixture, put them into thin glasses; and their orifices being stop'd and kept above the mixture, move them about therein, and then pour them out for drinking. By means hereof pieces of crystal, or bullets, may be powerfully cooled, to be held in the mouth or hands of those patients who require them; or other the like refreshment may be easily procured, with a very few ounces of sal-armoniac, well powder'd and suddenly dissolved in four times its weight of water. *

2. And to shew that a more intense degree of cold may result from the mixture, than was to be found in either of the ingredients apart; and also that a considerable coldness may be begun between bodies, neither of them actually cold before they were put together; having brought a glass full of water to such a temper, that its warmth made the spirit of wine in the sealed weather-glass manifestly ascend, I took out the thermometer, and laid it in powdered sal-armoniac, warmed before hand; whereby the tinged liquor was made to ascend much quicker than, just before, by the water; and having presently removed the instrument into that liquor again, and poured the warmish sal-armoniac into the same, I found, that within half a minute, or less, the spirit of wine began to subside, and fell above a whole division and a quarter, below the mark at which it stood in the water, before that liquor or the salt were warmed. Nor did the spirit, in a great while, re-ascend to the height it had when the water was cold. The same experiment we made at another time with the like success.

A coldness produced by the mixture of warm bodies.

3. To shew, likewise, how much the production of heat and cold depends upon texture, and other mechanical properties, I made a sal-armoniac after a particular manner, that I might know the effects of the ingredients, as well before, as after conjunction. I took, then, spirit of salt, and spirit of fermented, or rather putrefied urine; and having put a sealed weather-glass in an open vessel, into which one of them was poured, I added the other, by degrees, to it; and observed, that, as upon mixing, they made a great noise, with many bubbles, so in the conflict, they lost their former coldness, and impelled up the spirit of wine in the sealed thermometer; then, slowly evaporating the superfluous moisture, I obtained a fine sort of sal-armoniac, for the most part figured not unlike the other, when, being dissolv'd, and filtred, it is carefully coagulated. This new salt being gently dried, I put it into a wide glass of water, wherein I had before placed a sealed

* For a great degree of cold produced by mercury-sublimate, sal-armoniac, and distill'd vinegar; with many other cold dissolutions and fermentations, with the

mechanical account of them, See, *Philos. Transf.* N°. 274. p. 951. and the *French Memoirs.* A. 1700. p. 142.

PHYSICS.

weather-glass, that the included spirit might acquire the temper of the ambient liquor; and having stirred this salt in the water, tho' I took it then off the mantle-piece of a chimney, wherein there had been a fire for several hours before, it made the tinged spirit hastily subside.

*Heat produced
by the mixture
of cold bodies.*

4. We took a small seal'd thermometer, whose stem was divided into equal parts, by little specks of amel, that sharp liquors might not eat off or spoil the marks. The ball of this instrument we put into a slender cylindrical vessel, and more than cover'd it with strong oil of vitriol, and left it there a while to be reduc'd to the temper of the surrounding liquor. Then we cast upon it, by degrees, sal-armoniac grossly powder'd, which being soon furiously wrought on by the menstruum; a seeming effervescence was produced in the conflict, with great noise and much froth, which more than once was ready to run out of the vessel. But for all this seeming ebullition, the mixture, instead of growing hot, did really grow gradually colder, as appear'd not only to the touch, but by the descent of the tinged spirit of wine. But pouring this actually cold mixture into three or four times its weight of common water, that was likewise actually cold; this second mixture immediately grew so hot, that I cou'd not keep my finger for a minute or two upon the outside of the containing glass.

*Ebullition no
argument of
heat.*

5. We took an acid spirit, distilled from roch-alum, and put into a wide-mouth'd glass, more than was sufficient of it to cover the globular part of a good seal'd thermometer; then suffering the instrument to remain for some time in the liquor, to acquire the temper thereof, we put in, by degrees, some volatile salt, sublimed from sal-armoniac and a fixed alkali; when, notwithstanding the very numerous bubbles, and the noise and froth which were produced, as is usual upon the reaction of acids and alkalies, the tinged spirit in the weather-glass began a little to descend, and continued to do so, till the spirit of alum was glutted with the volatile-salt; the descent of the tinged liquor in the instrument amounting to an inch. By comparing this experiment with the first part of the third, it appears that when volatile and urinous salts or spirits tumultuate upon their mixture with acids; neither the heat nor the cold, which ensues, is produced by a conflict with the acids, merely upon account of their acidity; since we have seen, that an urinous spirit produced an actual heat with spirit of salt; and the distilled salt of sal-armoniac, which is also urinous, with the acid spirit of roch-alum, produces not a true effervescence, but a manifest coldness: as the same salt also did in a trial of another sort, which was this.

6. We took one part of oil of vitriol, and shaking it into twelve parts of water, made a mixture, which at first was sensibly warm; then suffering it to cool, we put a sufficient quantity thereof, into a wide-mouth'd glass, and placed in it a good thermometer hermetically sealed; the compound liquor, reaching a pretty way above its ball: after some time had been allow'd, for the liquor in the thermometer to acquire the temper of the external one; we gradually put in as much volatile salt of sal-armoniac, as satiated the acid spirits of the mixture.

ture. Now though these two made a notable conflict with noise and froth, yet it was but a cold ebullition; for the spirit in the thermometer descended about an inch beneath the mark it rested at, when the seeming effervescence began.

7. It is known that salt-petre being put into common water, produces a sensible coldness therein, as it doth also in many other liquors; but that the same salt, put into a liquor of another constitution, may have a quite different effect, appears by mixing eight ounces of fine salt-petre in powder, with six ounces of oil of vitriol: for here a salt, not only actually cold, but, with regard to many other bodies, potentially so, with the oil of vitriol, which is sensibly cold too, quickly conceives a considerable degree of heat, whose effects also become visible in the plenty of fumes, emitted by the heated mixture. And tho' gunpowder seems to be of a very fiery nature, yet if some ounces of it, reduced to powder, be thrown into four or five times as much water, it will very manifestly impart a coldness to it; as experience made with, as well as without, a sealed thermometer has assured me. This, and the foregoing experiment, suggests an inquiry into the nature of the coldness, which philosophers oppose to that which immediately, and upon the first contact, affects the organs of sense; and which, therefore, they call actual or formal. We repeated the former experiment with the same success; and the phenomenon is the more strange, because I have found, that a small quantity of oil of vitriol, not beforehand mixed with water, would produce a great heat in its conflict with a small portion of just such salt as I employ'd before: and this heat did, upon trial, with the same thermometer, make the tinged spirit ascend much farther than the other mixture made it subside.

*The same body
that cools some
liquors may
heat others.*

8. Potential coldness has been generally look'd upon as so abstruse a quality, that it seem'd necessary to derive it from the substantial forms of bodies. But I think it may be ascrib'd to mechanical properties. For as to the chief instances thereof, which are taken from the effects of some medicines and aliments in the human body, the coldness produc'd, may proceed chiefly from hence, that the body potentially cold, is made up of corpuscles of such size, shape, &c. that being dissolved, and disjoined by the menstruum of the stomach, or the fluids it may elsewhere meet with, they so associate themselves with the small parts of the blood, and other liquors, as by clogging them, or otherwise, to cause them to act in a peculiar way, and more slowly, on the nervous and fibrous parts: and the perception of this immutation of motion in the organs of feeling is that, which, being referred to the body producing it, we call its potential coldness. Which quality hence appears to be but a relative thing, and to require the diffusion of the small parts of the corpuscles of the agent, and their mixture with the liquors, or the small parts of the body they are to cool. And therefore, if it be granted that there is in agues, some morbid matter of a viscous, or not easily dissipable texture, harboured in some part of the body, which requires a determinate time to be made

*Potential
coldness.*

PHYSICS.

fluid, and resolvable ; the cold fits of agues need not appear surprizing ; since, tho' just before the fit, the same parcel of matter, which is to produce it, was actually in the body ; yet it was not, by reason of its clamminess, actually resolved into such parts, and mixed with those of the blood ; and consequently could not make such a change in the motion of that fluid, as is felt in the cold fit of an ague. And in some other diseases, a small quantity of matter, being resolved into minute parts, may produce a great sense of coldness in a particular part of the body, which, by reason of its structure, may be peculiarly disposed to be affected thereby ; as hysterical women complain of great coldness, which suddenly invades some particular part, as the head or back, and long continues to be troublesome there. And that, if a cold vapour or matter be exceeding subtil, an inconsiderable quantity of it, being dispersed through the blood, may produce a great degree of coldness, appears from the effects of some poisons. And it is not very material, whether the poison, generally speaking, be hot or cold, if it meets with a body disposed to have those affections, which pass for cold ones, produced in it. For I have made a chymical liquor, which, tho' fiery upon the palat, and possess'd of a briskness and a subtilty from distillation, given in the quantity of a single drop, wou'd immediately cast an animal into that which appear'd asleep ; and the like liquor, in the like quantity, being by mistake applied to an aching tooth, presently gave an universal coldness and trembling to the body, worse than the cold paroxysm of a quartan. And tho' scorpions, by their sting, sometimes cause violent heats in the parts they hurt, yet sometimes also, their poison proves in a high degree potentially cold ; as may be learn'd from the two following observations, of eminent physicians. " I had a servant," says *Benivenius*, " who being stung by a scorpion, immediately afterwards fell into so cold a sweat all over his body, that he complain'd he was every way cover'd with ice and snow. But he was presently relieved from it, and cured by a dose of *Venice* treacle given in some strong wine." And *Amatus Lusitanus* tells us of a man stung in the finger by a scorpion, whence great pain ensued, with an universal coldness and trembling, and the sense, as it were, of needles pricking his whole skin.

Perhaps in these great refrigerations, there may be some small concretions or coagulations made of the minute particles of the blood into little clots, more unweildy than they were, when separately moved ; as happens in the little curdlings, made of the parts of milk, by a very small proportion of some acid liquor ; or in the small coagulations made of the spirit of wine by that of urine. Perhaps also besides the slackening of the circulation of the blood, some poisons, and other analogous agents, may give the motion of it a new modification, and thereby cause it to grate, or act in a peculiar manner upon the nervous and fibrous parts of the body. And, as some parts of the human body greatly differ from others, in their structure and internal constitution ;
and

and since also some agents may abound in corpuscles of different shapes, bulks and motions; the same medicine may, with regard to the same human body, be potentially cold, or potentially hot, according as it is applied; or, perhaps, upon one or both of these accounts, be cold with respect to one part of the body, and hot in regard of another. And these effects need not be always ascribed to the mere, and immediate action of the corpuscles of the medicine, but sometimes to the new quality they acquire in their passage, by associating themselves with the blood, or other fluids of the body; or to the expulsion of some heating or cooling corpuscles; or to the disposition they give the part on which they operate, to be more or less permeated and agitated than before, by some subtle matter, or other efficient of heat or cold. Some of these conjectures, about the relative nature of bodies potentially cold, may be either confirmed or illustrated by such instances as these. Spirit of wine, internally taken, is potentially very hot, yet being outwardly applied to burns, and hot tumours, it considerably abates the heat of the inflamed parts; tho' the same spirit, applied even outwardly to a tender eye, will cause a great and painful agitation therein. And camphire, which, in the dose of less than an half a scruple, has been observed to diffuse an heat thro' the body, is, with success, externally applied in cooling medicines. But I leave the farther enquiry into the operations of medicines to physicians, who may possibly, by what has been said, be assisted to reconcile the differences of writers about the temper of those medicines, as mercury, camphire, &c. which some will have to be cold, and others hot; and shall only offer a few particulars to shew, in general, that potential coldness is only a relative quality. The first is afforded by comparing the two last experiments together; whence it seems probable, that the same thing may be potentially cold to one body, and not to another, according to the disposition of the body whereon it operates, or that operates upon it. The fumes of lead have been sometimes observed to arrest the fluidity of mercury, which change is supposed to be the effect of a potential coldness, belonging to lead, with regard to fluid mercury, tho' it have not that operation on any other liquor, that we know of. And lastly, tho' nitre, and sal-armoniac, be both apart, and jointly cold, with respect to water; and tho' nitre, however thoroughly melted in a crucible, will not of itself take fire, yet if, whilst it is in fusion, you, by degrees, cast on it some powdered sal-armoniac, it will take fire, and flash vehemently, almost as if sulphur had been thereon injected.

9. To twelve ounces of sal-armoniac, we put, by degrees, an equal weight of water; and whilst the liquor dissolved the salt, and by that action produced a great coldness, we warily poured in twelve ounces of good oil of vitriol; whence a notable degree of heat was quickly produced in the glass, wherein the ingredients were mixed; though it seem'd unlikely, that as each of

Heat produced by the joint action of two bodies upon a third, with which, separately, they two produce cold.

PHYSICS.

Heat and cold
accidentally
varied in their
production.

two liquors usually, with sal-armoniac, produce an intense cold, that both of them acting on it together, should produce the contrary quality.

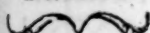
10. In most of the experiments hitherto proposed, cold is regularly produced in a mechanical way; but in some sort of trials, I found the event varied by unobserved circumstances; so that manifest coldness would be sometimes produced by mixing two bodies together, which, at another time, would upon uniting disclose a manifest heat; and sometimes again, tho' more rarely, would have but a very faint degree of either. Of this sort of experiments I found to be the dissolution of salt of tartar in spirit of vinegar, and some other salts, which were not acid, in the same menstruum: and even the spirit of verdigrease, (made *per se*) tho' a more powerful menstruum, than common spirit of vinegar, would not constantly produce near such an heat at the beginning of its operation, as the greatness of the seeming effervescence, then excited, would induce one to expect. To eight ounces of spirit of verdigrease (wherein we had a while before put a standard-thermometer, to acquire the like temper with the liquor) we added in a wide-mouthed glass two ounces of salt of tartar, as fast as we durst, for fear of making the liquor boil over; and tho' there was a great commotion excited by the action, and re-action of the ingredients, attended with a large froth, and a hissing noise; yet the glass did not soon become warm on the outside; but by that time the salt was all dissolved, the spirit in the thermometer appeared to have risen three inches and a half. On the other hand, I have found, that by mixing salt of tartar with another salt, the texture of the fixed alkali was so altered, that upon the affusion of spirit of verdigrease, tho' there ensued a great conflict with noise and bubbles, yet instead of heat, a considerable degree of coldness was produced.

11. It is very probable, that farther trials will furnish us with more instances, to shew how the production of cold may, in some cases, be effected, varied, or hinder'd by mechanical circumstances, which are usually overlooked. We observed, in the experiment lately mention'd, that tho' the oil of vitriol and water, being first shaken together, and the volatile salt of sal-armoniac, afterwards put to them, produced a sensible coldness; yet if a little oil of vitriol, and of the volatile salt were first put together, tho' soon after a considerable proportion of water was added, there would be produced not a coldness, but a manifest degree of heat, which impell'd the spirit in the thermometer to the height of some inches. I remember too, tho' salt of tartar grows hot in water, yet having distilled some of that, and cinnabar, in a strong fire, and put the whole *Caput mortuum* into distilled or rain-water, it made, indeed, an hissing there, as if it had been quick-lime, but produced no sensible heat. And not only some unheeded circumstances may promote or hinder the artificial production of cold by particular agents, but, perhaps, some hardly observable indisposition in the patient, may promote or hinder the effects of the grand, and universal efficient of cold;

cold; for I have sometimes found, that the degree of the operation of cold has been much varied by latent circumstances; some bodies being more wrought upon, and others less, than we, upon very probable grounds, expected. And particularly, I remember, tho' oil of vitriol be one of the most fiery liquors yet known, performs some of the operations of fire itself, and thaws ice, sooner than spirit of wine, or any other liquor; yet having put about a pound of fine rectified oil of vitriol into a strong glass-vial proportionable to it, we found that, except a little, which was fluid at the top, it was all congealed, or coagulated into a mass, like ice, tho' the glass stood in a laboratory, where a fire was constantly kept not far from it, and where oil of vitriol very seldom, or never, has before, or since, been observed to congeal so much as in part. The oddness of our phenomenon was increased by this circumstance, that the mass continued solid, for a long time after the weather was grown too mild to have such operations upon liquors, much more disposed to lose their fluidity by cold, than even common oil of vitriol. On the other hand, having exposed some oil of sweet almonds, hermetically sealed up in a glass-bubble, to observe what condensation an intense cold would make of it, (for tho' cold expands water, it condenses common oil;) I found the next day, that not only the oil remained unfrozen by the sharp frost, whereto it had been exposed; but that it had not its transparency diminished, tho' it is known that oil will be brought to concrete by a far less degree of cold, than is requisite to freeze water. This liquor, nevertheless, which was lodged in a glass, blown at the flame of a lamp, continued fluid, and transparent in very frosty weather so long, that I never expected to see it congealed. And tho' camphire is often reckoned potentially cold, yet some oil of it, wherein the whole body of the camphire remained, reduced by some nitrous spirits to that form, being kept in such intense degrees of cold, that would have easily frozen water, it lost not its transparency, or fluidity.*

* The power of congelation is not always proportionable to the degree of cold, but seems, in some measure, to depend on other alterations in the weather; and actual cold, seems not owing to a mere rest of parts among themselves; nor can hardness proceed from a mere deprivation of motion; whence it appears probable, since a mixture of cer-

tain salts with water give a great degree of coldness, and sometimes, when the proportions have been nicely hit, turn it to ice, that a particular kind of salt is the cause of congelation, by insinuating between the particles of water like nails, and fixing them together; tho' this is but a conjecture. See *Clark. Annot. in Robault. p. 117. 148.*



S E C T. II.

Heat mechanically producible.

Agitation requisite to heat.

Heat will appear the more likely to be mechanically producible, from considering the nature of it. And this seems principally to consist in that mechanical property of matter we call motion; which is subject to three conditions. First, the agitation of the parts must be vehement; for this distinguishes the bodies said to be hot, from those which are barely fluid. Thus the particles of water, in its natural state, move so calmly, that we do not feel it at all warm, tho' it could not be a liquor, unless they were in a restless motion; but when water comes to be actually hot, the motion manifestly, and proportionably appears more vehement; since it does not only strike our organs of feeling briskly, but ordinarily produces numerous very small bubbles, melts coagulated oil cast upon it, and affords vapours, which, by their agitation, ascend into the air. And if the degree of heat be such, as to make the water boil, then the agitation becomes much more manifest, by the confused motions, waves, noise, bubbles, and other obvious effects excited therein. Thus in a heated iron, the vehement agitation of the parts may be easily inferred from the motion, and hissing noise it makes with the drops of water, that fall upon it. And fire, which is the hottest body we know, consists of parts so vehemently agitated, that they perpetually fly off in swarms, and dissipate all the combustible bodies they meet with in their way; making so fierce a dissolution, and great consumption of its own fuel, that we may see whole piles of solid wood so dissipated into flame, and smoke, that sometimes there will not be one pound of ashes remaining.

And various determinations.

The second condition is, that the determinations be very various, and tend all manner of ways. This variety of determinations appears to be in hot bodies, both by some of the instances already mentioned, and especially that of flame, which is a body; by the diffusion, which metals acquire, when melted; and by the operations of heat, exercised by hot bodies upon others, in what posture or situation soever the body, to be heated thereby, is applied to them. Thus a coal, thoroughly kindled, will appear on all sides red, and melt wax, and kindle brimstone, whether the body be applied to the upper, the lower, or to any other part of it. And according to this notion, tho' air and water be moved ever so vehemently, as in high winds, and cataracts, yet we are not to expect they should thence become manifestly hot; because the vehemence belongs to the progressive motion of the whole body; notwithstanding which, the parts it consists of may not be near so much accelerated in the motions, made according

ing to other determinations, as to become sensibly hot. No wonder then, that, in some cases, where the whole body tends but one way, it is not perceived to be made hot thereby. PHYSICS.

Nay, tho' the agitation be very various, as well as vehement, there is yet a third condition required, to make a body hot. For the agitated particles, or at least, the greatest number of them, must be so minute, as to be singly insensible. Were an heap of sand to be vehemently agitated by a whirl-wind, the bulk of the corpuscles would keep their agitation from being properly heat; tho' by their numerous strokes upon a man's face, and the brisk commotion of the spirits, and other small particles, which may thence ensue, they may perhaps produce that quality.

That the moving particles should be small.

1. Hence, if we duly attend to this notion of the nature of heat, 'tis easy to discern, how it may, several ways, be mechanically produced. For, except in some few anomalous cases, by whatever means the insensible parts of a body are put into a very confused and vehement agitation, heat will be introduced into that body. And as there are several agents and operations, by which this heating motion may be excited; so there must be several mechanical ways of producing heat. Various experiments may be reduced to almost each of these heads; chance itself having, in the laboratories of chymists, afforded several phenomena, referable thereto. Many of the more familiar instances, applicable to this purpose, are collected by the lord *Verulam*, in his excellent paper, *De formâ calidi*. There are several causes assign'd for the heat observed in quick-lime, upon the affusion of cold water; which to me seem either justly questionable, or manifestly erroneous. The schools tell us, it happens by virtue of an antiperistasis, or invigoration of the internal heat of the lime, upon its being surrounded by cold water: but this is an imaginary cause; for if the water be poured on very hot, the ebullition of the lime will not be the less, but rather greater: and oil of turpentine, which is a lighter, and more subtile liquor than water, will not, tho' poured on cold, grow sensibly hot with it. *Helmont* indeed, and his followers, have attempted to derive this heat, from the conflict of some alkalizate and acid salts of the quick-lime, which are dissolved, and so set at liberty to fight with one another, by the water that flakes it. But tho' we have some manifest marks of an alkalizate salt in lime, yet that it contains, also, an acid salt, has not been proved; and if the heat be a sufficient reason to prove a latent acid salt in lime, why may we not infer, that the like salt lies concealed in other bodies, which the chymists take to be of the purest sort of alkalies? For I have purposely tried, that, by putting a considerable quantity of dry salt of tartar in the palm of my hand, and wetting it well with cold water, there has been a very sensible heat produced in the mixture: and when I have made the trial, with a larger quantity of salt and water, in a vial, the heat proved very intense, and continued to be sensible for a long time after.

Various mechanical ways of producing heat.

PHYSICS.

2. This experiment seems to shew, that the heat proceeds from the empyreuma, or impression left by the violent fire, that reduced the stone to lime. But if by empyreuma, we mean a bare impression made by the fire, 'twill be difficult to shew wherein it consists, and how it operates in this case. The effect may be, also, ascribed to swarms of fiery particles, adhering to the substance of the lime, and set at liberty to fly away, by the liquor; as may be conjectured from the flaking of lime, left, for some time, in the air, whereby the atoms of fire have an opportunity to fly gradually away. And, doubtless, we may admit the co-operation of a substantial effluvium of the fire, in accounting for the phenomenon. But it is not easy to apprehend, that such light and minute bodies should be so long detained, as must by this hypothesis be allowed, in quick-lime; especially since no great heat ensues the pouring of water upon minium, or *Crocus Martis per se*, tho' they have been calcined by a violent fire, the effluvia whereof seem to adhere to them, by the increase of weight, that lead and iron manifestly receive from the operation of it. And tho' one would think, that the fiery atoms should either fly off, or be extinguished by the water; yet I have made an experiment, in which two liquors, whereof one was natural, did, by being several times separated, and re-conjoined without addition, at each conjunction produce a sensible heat. And an instance of this kind, we have in salt of tartar, from which, after it had been once heated by the affusion of water, we abstracted the liquor, without violence of fire, till the salt was again dry; and then putting on water a second time, the same salt grew hot again in the vial, and produced the like heat a third time, and might probably have done it oftener: which seems, at least, to argue, that the great violence of fire is not necessary to impress what passes for an empyreuma, upon all the calcined bodies, which will grow hot with water. Perhaps, also, the heat may much depend upon the particular disposition of the calcined body, which, being deprived of its former moisture, and made more porous by the fire, acquires, by means of those igneous effluvia, such a texture, that the water, impelled by its own weight, and the pressure of the atmosphere, is able to get into a multitude of its interstices at once, suddenly dissolve the alkalizate salts it every where meets with, and briskly disjoin the earthy and solid particles, that were blended with them; which being exceeding numerous, tho' each of them perhaps be very minute, and moves but a very little way, yet their multitude makes the confused agitation of the whole aggregate, and of the particles of the water and salt vehement enough to produce a sensible heat; especially, if we admit such a change in the pores, as greatly increases this agitation, by the entrance and action of a subtile ethereal matter, from which, alone, M. Des-Cartes attempts to derive the heat produced by lime and water, as well as that of metals dissolved in corrosive liquors. But in our phenomena, there seems, at least, to concur a peculiar

cular disposition of the body, wherein heat is produced, to retain many fiery effluvia, and to be, by their adhesion, or some other operation of the fire, reduced to such a texture of its component particles, as fits it to have them easily penetrated, and greatly dissipated by water. And this conjecture seems favoured by various phenomena. It may be observed, that both the dissolved salt of tartar, lately mentioned, and the artificial liquor, which grows hot with the natural one, re-acquires that disposition to heat, upon a bare condensation, or closer texture of the parts, from the exhalation of the superfluous liquors, wherein they were before dispersed: the heat, which brought them to this texture, having been so gentle, that it is no ways likely, the fiery exhalations could, themselves, produce such an one; or at least, that they should adhere in numbers sufficient to that end, unless the texture of the salt, or other body, peculiarly disposed it to detain them; since I have found by trial, that sal-armoniac, dissolved in water, tho' boiled up with a brisker fire, to a dry salt, would not, upon its being again dissolved in water, produce any heat, but a very considerable degree of cold. And tho' a great likeness might be expected between the particles of fire adhering to quick-lime, and those of highly rectified spirit of wine; yet I have not found, that the affusion of that spirit upon quick-lime produced any sensible heat, or visible dissolution of the lime, tho' it seemed to be greedily suck'd in, as common water would have done. And I farther tried, that if cold water was poured on this lime, so drenched, there ensued no manifest heat: nor did the lump appear swelled, or broken; till some hours after; which seems to argue, that the texture of the lime admitted the particles of the spirit of wine into some of its pores, which were either larger, or more fit, without admitting it into the most numerous, whereinto the liquor must be received, to be able suddenly to dissipate the corpuscles of lime into their minuter particles. I also made an experiment, which seems to favour our conjecture, by shewing how much the disposition of lime to grow hot may depend upon a suitable texture. Upon quick-lime placed in a retort, we put as much spirit of wine, as would swim pretty high above it; when, distilling with a gentle fire, we drew off some spirit much stronger than that which had been put on; and then the phlegm following it, the fire was increased, which brought over a large quantity of weak liquor; by which, one would have thought, that the quick-lime had been flaked; but the remaining matter being taken out of the retort, and suffered to cool, it appeared to have a fiery disposition, which it had not before. For if any lump of it, as big as a nutmeg, was cast into water, it would hiss like a coal of fire plunged into the liquor, which was thereby soon sensibly heated. Nay, having kept several lumps of this prepared calx well secured from the air, for many weeks, to try whether it would retain this property, I found it operate after the same manner, but more powerfully. For sometimes it would, upon its coming

PHYSICS. into the water, make such a brisk noise, as might almost pass for explosion.

3. These phenomena seem to shew, that the disposition, which lime has to grow hot with water, greatly depends on some peculiar texture; since the aqueous parts, which, one would think capable of quenching most of the fiery atoms supposed to adhere to quick-lime, did not near so much weaken the disposition of it to heat, as the access of the spirituous corpuscles, and their contexture with those of the lime, increased it. And that such an association might happen, seems the more probable, because much of the distilled liquor was as phlegmy, as if it had been robbed of its more active parts; and because I have sometimes had spirit of wine come over with quick-lime, not in unobserv'd steams, but white fumes. We may add, besides that the taste, and perhaps scent of the spirit of wine, is often manifestly changed by a well regulated distillation from quick-lime; I have some times found that liquor to give the lime a kind of alkalizate penetrancy of taste, or fieriness, which was very brisk and remarkable: tho' I have found quick-lime to differ greatly, not only with the degree of its calcination and freshness, but also according to the various nature of the stones, and other bodies calcined to make it.

4. To come to the production of heat, wherein there appears nothing on the part of the agent or patient, but motion, and its natural effects. When a smith briskly hammers a small piece of iron, the metal thereby becomes exceeding hot; yet there appears nothing to make it so, except the forcible motion of the hammer, impressing a vehement, and variously determined agitation on the small parts of the iron; which being a cold body before, grows, by that superinduced commotion of its small parts, in several senses hot. First, in a more loose acceptation of the word, with regard to some other bodies compared with which it was cold before, then sensibly hot; because this agitation surpasses that of the parts of our fingers. And in this instance, oftentimes, neither the hammer nor the anvil continues cold, after the operation; which shews, that the heat acquired by the forged piece of iron was not communicated by the hammer or anvil, as heat, but produced in it by a motion, great enough strongly to agitate the parts of so small a body as the piece of iron, without being able to have the like effect upon so much greater masses of metal, as the hammer and the anvil; tho' if the percussions were often and briskly renewed, and the hammer were small, this also might be heated; whence it is not necessary that a body should be it self hot, to give heat. And if a large nail be driven by a hammer into a plank of wood, it will receive several strokes on its head, before it grows hot; but when it is once driven to the head, a few strokes suffice to give it a considerable heat; for whilst, at every blow of the hammer, the nail enters farther into the wood, the motion produced is chiefly progressive, and is of the whole nail, tending one way; but when that motion ceases, the impulse given by the stroke, being unable either to drive the nail further on, or break it, must be spent in making a various, vehement, and

and intestine commotion of the parts among themselves; wherein the nature of heat consists.

5. In the foregoing experiment, the brisk agitation of the parts of a heated iron was made sensible to the touch; I shall now add an attempt I made to render it discoverable to the eye itself. In order to this, I caused a bar of iron to be briskly struck upon by two or three lusty men, accustomed to the hammer, who dealing their strokes with as much force, and as little intermission as possible, soon render'd it too hot to be safely touched; and it would, probably, have fired gun-powder, if the metal I was obliged to use had been of the best sort: for it kindled the sulphur of many corns of that powder, and turn'd them blew. But, besides the effects of violent percussion, there are some obvious phenomena, which shew the producibleness of heat in cold iron, by causing an intestine commotion of its parts. We find, that if a piece of iron, of a convenient shape and bulk, be briskly filed with a large rough file, a considerable degree of heat will be quickly excited; the many prominent parts of the instrument giving a multitude of strokes to the parts of the iron, which happened to stand in their way, and thereby making them put the neighbouring parts into a brisk and confused motion, and consequently into a state of heat. It must not be here objected, that, upon this account, the file itself ought to grow as hot as the iron; since, the whole body of the file being continually moving backwards and forwards, the same parts, that touch the iron one moment, pass off the next; and, besides, have leisure to cool themselves, by communicating their agitation to the air, before they are brought to grate again upon the iron, which being held immovable, receives almost perpetual shocks in the same place. We find also, that vehement attrition produces heat in the most solid bodies; as when the blade of a knife is strongly whetted; or a brass nail rubbed against a board. And I remember, that, driving our coach very fast, in exceeding hot weather, the attrition of the nave of the wheel against the axle-tree was so vehement, as obliged us to cool the parts with water, to stop the growing mischief. The common experiment of striking fire with a flint and steel, sufficiently declares, what heat may, in a trice, be produced in cold bodies by percussion or collision; the latter of which seems but mutual percussion.

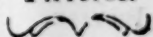
6. For the sake of those who think the attrition of contiguous air necessary to produce manifest heat, we placed some hard black pitch in a basin, at a convenient distance under water, and cast the sun's rays on it, with a burning-glass, in such a manner, that, notwithstanding the refraction they suffered in passing thro' the water, the focus falling upon the pitch, would produce sometimes bubbles, sometimes smoke, and quickly communicate a degree of heat able to melt it, if not also to make it boil.

7. We have shewn that a considerable degree of cold is produced by the dissolution of sal-armoniac in common water; yet the texture of it
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may, by an addition, be so alter'd, that a great degree of heat will arise upon dissolving it therein. We flaked quick-lime in common cold water, that all the fiery, or other particles of it, to which its power of heating that liquor is ascribed, might be extracted and imbibed, and so the remaining calx be freed from them; on this calx we often poured fresh water, that all adhering reliques of salt might be washed off. Then the dulcified powder, being again well dried, was mixed with an equal weight of powdered sal-armoniac; and having, in a strong fire, melted the mass, the mixture was poured out; and being afterwards beaten to powder, having allowed it a competent time to grow cold, we put two or three ounces of it into a wide-mouth'd glass; and pouring water upon it, within about a minute the mixture grew warm, and quickly attained so intense a heat, that I could not hold the glass in my hand. And tho' this heat did not last long at the same height, it continued to be very sensible for a considerable time. And to confirm this experiment by a notable variation; we took, finely powdered, sal-armoniac, and filings of steel; and when they were very well mixed, we caused them to be gradually sublimed in a glass-vessel; giving a smart fire towards the latter end. By this operation, so little of the mixture ascended, that far the greatest part of the sal-armoniac staid at the bottom with the metal; then taking out the *Caput mortuum*, I gave it time to cool thoroughly, but in a glass well stop'd, that it might not imbibe the moisture of the air: and lastly, tho' both these bodies were actually cold, and so might be thought likely to increase, and not check the coldness usually produc'd in water by that salt; yet putting the mixture into common water, there ensued an intense degree of heat. And having sublimed the foresaid salt, in distinct vessels, with the filings of steel, and with filings of copper, and kept one of their remainders after distillation, for several months; we, at length, took it out of the vessel, which had been carefully stopp'd, and found that the disposition to give cold water a great degree of heat was still preserved in it.

8. If experiments were made after the same manner, with sal-armoniac, and other mineral bodies, besides iron, and copper, it is probable, that some of the phenomena thence arising, would confirm what we have said of the interest of texture, and some few other mechanical properties in the production of heat and cold. For, three ounces of antimony, and an equal weight of sal-armoniac, being well powdered, mixed, and, by degrees of fire, sublimed in a glass-vessel, we obtained three different substances, which we caused to be separately powdered as soon as taken out of the subliming glass, lest the air should make any change in them; and having before set the ball of a good seal'd weather-glass, for a time, into water, that the spirit of wine might be brought to the temper of the external liquor, we put in two ounces of the powdered *Caput mortuum*, which seeming to be little other than antimony, scarce sensibly raised the spirit of wine in the thermometer.



meter. Then laying aside that water, and putting the instrument into fresh, of the same temper, we added to it a very yellow sublimate, which ascended higher than the other parts, and seemed to consist of the more sulphureous flowers of the antimony, with a mixture of the more volatile parts of the sal-armoniac. And this substance made the tinged spirit in the thermometer descend, very slowly, about a quarter of an inch; but when the instrument was put into fresh water of the same temper, and we had added some of the powder of the lower sort of sublimate, which was dark-coloured; tho' both the antimony, and sal-armoniac it consisted of, had been long exposed to the action of a subliming heat, yet the water was thereby soon cooled, so that the spirit of wine in the weather-glass hastily descended, and continued to sink, till it had fallen near three inches. We made a like experiment by subliming minium and sal-armoniac, each three ounces; and found, that tho' in the *Caput mortuum*, the salt had notably wrought upon the calx of lead, and was in part associated with it; yet a convenient quantity of this powder'd mixture being put into water, wherein the former weather-glass had been kept a while, the spirit of wine was not manifestly either raised or depress'd. And when, in another glass, we prosecuted the trial with the sal-armoniac, which had been sublimed from the minium, it did, indeed, make the spirit of wine descend; but scarce a quarter so much as it had been made to fall by the former sublimate of sal-armoniac and antimony.

9. The heat arising in the dissolution of metals, is often ascribed to a supposed antipathy, occasioning a conflict, or hostility, between the contending bodies; and particularly between the acid salt of the one, and the alkalizate salt of the other. It will, therefore, be proper to offer some instances of the production of heat, by the operation of one agent, oil of vitriol; whence we may consider, whether it be likely, that this single agent should, upon account of antipathy, or that of its being an acid, produce an intense heat in many bodies of very different natures. Take some ounces of strong oil of vitriol, and shaking it with three or four times its weight of common water, tho' both the liquors were cold, when put together, yet their mixture will immediately grow intensely hot, and continue considerably so for some time. In this case, it cannot be pretended, that the heat arises from the conflict of the acid and alkalizate salts, abounding in the two liquors; since the common water is supposed an elementary body, free from all salts; at least, being an insipid liquor, it can scarce be thought to have alkali enough, to produce so intense a heat, by its re-action. That the heat arising upon such a mixture will be very great, when the quantities of the united liquors are large, may be easily concluded from hence, that I found no more than two ounces of oil of vitriol, being poured into four ounces of distilled rain-water, made, and kept it manifestly warm for above an hour; so that, during no small part of that time, it was painful to handle it.

Heat produced
by mixing the
same body,
with others of
several kinds.

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PHYSICS.

It seems extravagant to talk of heating cold liquors with ice; but I have easily done it, by taking out of a basin of cold water, wherein several fragments of ice were swimming, one piece or two, which I perceived were well drenched with the liquor, and suddenly immersing them into a wide-mouth'd glass, of strong oil of vitriol: for the menstruum, presently mixing with the water which adhered to the ice, produced in it a brisk heat, sometimes with a manifest smoke; and that suddenly dissolving the contiguous parts of ice, and those the next, the whole ice was soon reduced to water; and the corrosive menstruum being, by two or three shakes, well dispersed thro' it, the whole mixture would immediately grow so hot, that sometimes the containing vial could not be endured in one's hand.

Notwithstanding the vast difference between common water, and highly rectified spirit of wine; I found that oil of vitriol, mixed with the latter, would as well grow hot, as with common water. Nor does this experiment always require great quantities of liquor: for when I took but one ounce of strong oil of vitriol, tho' I put to it less than half an ounce of excellent spirit of wine, yet the two being lightly shaken together, immediately conceived so brisk a heat, that they almost filled the vial with fumes; and made it so hot, that I had like to have burnt my fingers with it, before I could lay it aside. I made the like experiment with the same corrosive menstruum and common *Aqua vita*; by the mixture whereof, a heat was produced in the vial, which I could not well endure. The like success I had when oil of vitriol was mixed with common brandy; only here the heat produced, seemed not so intense, as in the former trial; which also did not afford so fierce a heat, as that made with rectified spirit of wine.

Those chymists who conceive, that all the heat of bodies, upon their being mixed, proceeds from their antipathy or hostility, will hardly expect, that the parts of the same body should, without conflict, grow very hot together. Yet having put two ounces of colcothar, calcin'd almost black, into a retort, we poured upon it two ounces of strong oil of *English* vitriol, and found, after about a minute, they began to grow so hot, that I could not endure to hold my hand at the bottom of the containing vessel; and this continued sensible on the outside, for between twenty and thirty minutes.

I have not observed any liquor, with which oil of vitriol will grow more hot, than with common oil of turpentine. Causing several ounces of each to be well shaken together in a strong vessel, fastened to the end of a pole, to prevent mischief; the ebullition was surprizingly great and fierce. This calls to mind a pleasant adventure afforded by these liquors, of each of which, having, for the production of heat, and other purposes, caused a large bottle full to be put up, with other things, into a box, and sent down into the country, with a charge, that great care should be had of the glasses; the waggon in which

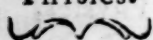
which the box was carried, happened, by a great jolt, to be so shaken, that these glasses were both broken; and the liquors mixing in the box, made such a noise, and stink, and sent out such quantities of smoke by the vents, which the fumes had opened, that the passengers, with great out-cries, hastily threw themselves out of the wagon, for fear of being burnt in it.

But tho' Petroleum, especially when rectified, be a most subtile liquor, and the lightest I have had occasion to try; yet to shew how much the heat of liquors may depend upon their texture, having gradually mixed one ounce of rectified petroleum with an equal weight of strong oil of vitriol; the former seemed to work upon the surface of the latter, almost like a menstruum upon a metal; innumerable small bubbles continually ascending, for a while, into the *Oleum Petra*, which had its colour manifestly alter'd, and deepened by the operation of the spirituous parts. But by all the action and re-action of these liquors, there was produced no such smoking and boiling, or intense heat, as if oil of turpentine had been employed; the change produced as to qualities, being but a kind of warmth, discoverable by the touch. Almost the like success we had in the conjunction of petroleum and spirit of nitre.

It were easy to multiply instances of heat producible by oil of vitriol upon solid bodies, especially upon minerals. In the usual preparation of *Vitriolum Martis*, there is a great effervescence excited upon the affusion of the oil of vitriol upon the filings of steel, especially if they be well drenched in common water. And it can scarce be doubted, that since oil of vitriol will dissolve a great many both calcined and testaceous bodies, as I have tryed with lime, oyster-shells, &c. so it will, during the dissolution, grow sensibly, if not intensely hot with them; as I found it to do both with those just mentioned, chalk, *Lapis calaminaris*, &c. with the last of which, if the liquor be strong, it will become exceeding hot.

Let us, therefore, proceed to its operation upon vegetables, which corrosive menstrooms have scarce been thought fit to dissolve and grow hot with. To omit cherries, and several other fruits, abounding in watery juices, with which, perhaps, on that account, oil of vitriol will grow hot; having mixed a quantity of this liquor with raisins of the sun, beaten in a mortar, the raisins grew so hot, that the glass, which contained them, almost burnt my hand. This kind of heat may also be produced by the mixture of oil of vitriol with many other vegetable substances; but as far as I have observed, scarce so eminently with any dry body, as with crumbs of bread; with a little of which, and strong oil of vitriol, we have sometimes produced a surprising degree of heat. It is as little observed, that corrosive menstrooms will work on the soft parts of dead animals, as on those of vegetables; yet I have, more than once, produced a notable heat, by mixing oil of vitriol with minced flesh, whether roasted or raw.

PHYSICS.



Tho' common sea-salt usually imparts some degree of coldness to common water, during its dissolution; yet some trials have informed me, that, if thrown into a competent quantity of oil of vitriol, a heat will, for the most part, ensue; tho' it yet did not appear to succeed so regularly, as in most of the foregoing experiments. But that heat should be usually produced, by oil of vitriol and salt, seems the more remarkable, because common salt is one principal ingredient of common factitious sal-armoniac. And I have been informed, that in the academy at *Florence*, oil of vitriol has been observed not to grow hot, but cold, by being put upon sal-armoniac: and something like this I took notice of in rectified spirit of sulphur *per Campanam*; but found the effect much more considerable, when, according to the *Florentine* experiment, I made the trial with oil of vitriol.

Other ways of
producing
heat, in solids,
powders, me-
tals, &c.

10. To proceed to some other experiments, wherein oil of vitriol is not concerned. We took a large lump of common sulphur, and having chafed it well, found it thereby grow sensibly warm; and that there was an intestine agitation made by this attrition, appear'd not only from the heat, whose nature consists in motion, and the antecedent pressure, which was fit to put the parts into a disorderly vibration, but also by the sulphureous steams, which were easily smelt by holding the sulphur to the nose. This experiment, tho' it seems trivial in itself, may be worth the consideration of those chymists, who derive all the fire and heat we meet with, in sublunary bodies, from sulphur. For, in our case, a mass of sulphur, before its parts were put into a new and brisk motions was sensibly cold; and as soon as its parts were put into a greater agitation than those of a man's fingers, grew sensibly hot; which argues, that it was not by its bare presence, that the sulphur communicated any heat to the hand; and also, that when briskly moved, it impress'd that quality, it did no more than another solid body, tho' incombustible, as common glass, would have done, if its parts had been likewise put into an agitation surpassing that of the organs of feeling: so that in our experiment sulphur itself was beholden, for its actual heat, to local motion, produced in its parts by external agents.

We thought proper to try, whether, when sal-armoniac, which greatly cools water, and quick-lime, which is known to heat it, were, by the fire, exquisitely united, the mixture would impart to the liquor any intense degree of either quality. To this end, we took equal parts of sal-armoniac, and quick-lime, and fluxed them together, and putting an ounce of the powdered mixture into a vial, with a convenient quantity of cold water, I found the dissolved mass, in about a minute, strike so great a heat thro' the glass upon my hand, that I was glad to remove it hastily, for fear of being scorched.

We have given several instances of the heat of mixtures, wherein both the ingredients were fluid, or at least, one of them; but sometimes heat may be produced, also, by the mixture of two powders:
for

for it has been observed in the preparation of the butter or oil of antimony, that if a sufficient quantity of beaten sublimite, be very well mixed with powdered antimony, the mixture, after it has, for a competent time, stood in the air, would sometimes grow manifestly hot, and now and then to that degree, as to send out vast fetid fumes, almost as if it would take fire.

There is another experiment, made by the help of antimony, and a pulverized body, wherein the mixture, after it had been exposed to the air for several hours, visibly afforded us mineral fumes. But in this case, perhaps, there happens unobservedly an aqueous moisture, which, I suspected, may be attracted from the air; since the mixture of the antimony and the sublimite, designed for the butter of antimony, is prescribed to be placed in cellars; where we find that sublimite, at least the saline part of it, is dissolved *per deliquium*.

I have given some instances of the heat produced by water in bodies, which are readily dissolv'd in it, as salt of tartar, and quicklime; but one would not expect that mere water should produce heat in solid bodies, which are generally granted to be insoluble in it; yet trial has assured me, that this may be done in flower, or fine powder of sulphur, and filings of steel or iron. For when, in summer-time, I caused a pound of each to be first mixed and thoroughly drenched with common water, wherein they were very well stirred, the mixture would, in a short time, grow so hot, that the containing vessel could not be suffered in the hand: a strong sulphureous smell, and a thick smoke were, also, produced thereby.

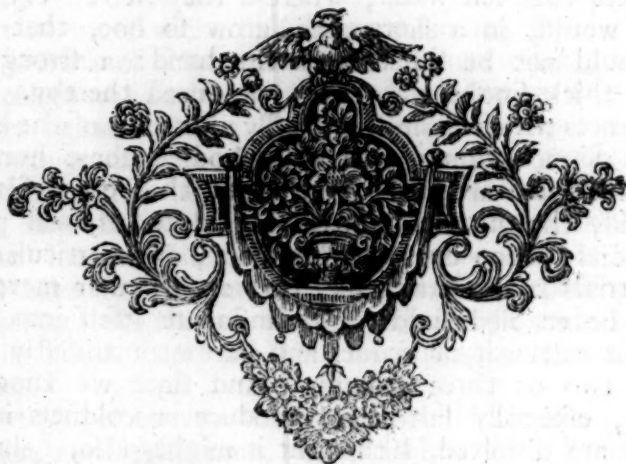
In the instances which chymistry usually affords us of the heat produced by the action of menstruums upon other bodies, some humid liquor is concern'd; and there are many who deny, that quick-silver, which is indeed a fluid, tho' not moist with regard to us, will produce heat by its immediate action on any other body, and particularly on gold: but several trials have assured me, that a particular mercury may, by preparation, be enabled suddenly to insinuate itself into the body of gold, whether calcined, or crude, and become manifestly hot with it, in less than two or three minutes. And since we know that some natural salts, especially salt-petre, produce a coldness in the water wherein they are dissolved, I thought it might, also, help to discover the structure of metals, and the salts that corrode them, if solutions were made of some bodies, which consist of metalline and saline parts; and so abound with the latter, that the whole concrete is on their account dissoluble in common water: of this sort of experiments, I shall here only take notice of one, that we made upon quick-silver, which is esteemed the coldest of metals. From this, having distilled four times its weight of oil of vitriol, and thereby reduced it to a powder, which, on account of the adhering salts of the menstruum, was white and glittering; we put this powder into a wide-mouth'd glass of water, wherein a sealed weather-glass had before been left,

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PHYSICS.

when, it began manifestly to heat it; as appeared by the quick and considerable ascent of the tinged spirit, that continued to rise upon putting in more of the magistery. This event is the more remarkable, because *Helmont* observes, that the salt adhering to the mercury, corroded by oil of vitriol, becomes, if it be washed off, and coagulated, a kind of alum; and still more, because having, after the same manner, and with the same weather-glass, made an experiment with common water, and the powder of *Vitriolum Martis*, prepared with oil of vitriol, and the filings of steel; the tinged spirit was not at all impell'd up as before, but rather, after a while, began to subside, and fell, tho' very slowly, about a quarter of an inch. The like experiment being tried with powdered sublimate in common water, the liquor in the thermometer was scarce at all, sensibly, either raised, or depress'd; which argued the alteration, as to heat or cold, to have been either none, or very inconsiderable.



MEMOIRS

FOR AN

EXPERIMENTAL HISTORY

OF

COLD.

1. *EXperiments with bodies capable of freezing others.*
2. *EXperiments and observations upon bodies disposed to be frozen.*
3. *Experiments upon bodies indisposed to be frozen.*
4. *Experiments and observations about the degrees of cold in several bodies.*
5. *Experiments of the tendency of cold, upwards or downwards.*
6. *Experiments and observations of the preservation and destruction of bodies by cold.*
7. *Experiments of the expansion of water and aqueous liquors by freezing.*
8. *Experiments of the contraction of liquors by cold.*
9. *Experiments in consort, relating to the bubbles, from which the levity of ice is supposed to proceed.*
10. *Experiments about the measure of the expansion and contraction of liquors by cold.*
11. *Experiments of the expansive force of freezing water.*
12. *Experiments about a way of estimating the expansive force of congelation, and of highly compressing air without engines.*

*Heads for an
experimental
history of cold.*

13. *Expe-*

PHYSICS.

13. Experiments and observations to determine the sphere of activity of cold.
14. Experiments about different mediums, thro' which cold may be diffused.
15. Experiments and observations upon ice.
16. Experiments and observations of the duration of ice and snow, and the destruction of them by the air, and several liquors.
17. Considerations and experiments upon the *Primum Frigidum*.
18. Experiments and observations as to the coldness and temperature of the air.
19. The strange effects of cold.
20. Experiments upon the weight of bodies frozen and unfrozen.
21. Promiscuous experiments and observations upon cold.

I.

Our senses and the common thermometers may misinform us of cold.

TO examine solicitously into the way of estimating the coldness of bodies, will, to many, appear a needless task; the organs of feeling, being generally thought the proper judges hereof: and, accordingly, both the ancient and modern philosophers seem to have taken up with this bare information of the matter. But as too much care cannot be shewn in examining the criteria of things, we shall take a closer view of this subject. For tho' cold, in its obvious idea, has relation to the sense of feeling, yet it remarkably affects many other bodies besides ours, and in some of them produces more sensible and less uncertain changes; and, therefore, in estimating the degrees of this quality, we ought to observe its effects in those bodies: for our senses, alone, or assisted by the common weather-glasses, are not to be relied on in this particular. To render the assertion credible, let it be consider'd, that the reason why a body is usually said to be cold is, that we feel its particles less agitated than those of our fingers, or other organs of touch; whence, as the temper of that organ changes, the object may seem more or less cold, while it remains uniformly the same. Thus we find in bathing, the milder degree of heat pass'd thro' to prepare us for the greater, seems very hot, when we immediately change it for the open air; and even chilling cold, upon returning back from the sweating-room. But besides these obvious changes, there are other secret ones, in the disposition of our organs, that require a philosophical head to observe them. For taking our temper to be the same, when no manifest cause of its alteration appears, we frequently impute to objects what resides in our selves; when, if the change be wrought by unsuspected agents, or by insensible degrees, we are apt to overlook it. Many cellars are, perhaps,

haps, no colder in the summer, than in winter, or the spring, tho' they will feel cold to us, who descend into them, with bodies heated by the summer's sun, and accustom'd to a warmer air. Nay, cold so greatly depends upon the agitation of the parts of the object, that even when the organ seems unalter'd, it may refer a degree of coldness thereto, which that really hath not. Thus air, blown out of a pair of bellows upon an exact thermometer, appears not to acquire any coldness, by being turn'd into wind, tho' any part of our bodies wou'd judge it cold; the reason whereof is, that tho' the organ remains unchanged, the wind, by its motion, drives away the air contiguous to the skin, together with the warm effluvia of the body which temper'd its coldness, and also penetrates deeper into the pores of the skin, where it is less agitated than the internal parts, and consequently feels colder. There may likewise, at particular times, be certain exhalations in the air which have a secret power of chilling the blood and spirits of human bodies; for opium, externally applied, strikes a coldness into the body by the subtile effluvia it sends thro' the pores of the skin. Perhaps, also, that coldness is ascribed to external causes, which some cold vapour, or very slight disease produces in us, bearing resemblance to what the physicians term horrors and rigors, at the beginning of fevers, &c. or occasioning that strange, universal coldness of the external parts, which is a common symptom in hysterical cases. Again, bodies may often seem colder to us than we shall find them by the thermometer; because our organs are more affected by the density and insinuation of particles, than the instrument. This I have frequently experienced in very nice thermometers; for water has appeared sufficiently cold to our touch, when the glass shew'd it to be no colder than the air.

1. *June 26.* between two and four of the clock in the afternoon, the weather being seasonable, I plunged the open stem of the small glass egg C D B A, into water, whence it received a cylinder of that fluid, about half an inch in length, which subsided, when the glass was erected perpendicularly, by its own weight, or by means of the temper of the included air, to the lower part of the pipe next the egg; then immersing the egg in a basin of cold water, the small cylinder that lay between the external and internal air, presently ascended from the lower part of the pipe to the middle thereof; and being taken out of the water, and placed again in the air, the cylinder would again subside, whether the glass were sustained by my fingers, or suffered to rest alone. This experiment I several times repeated: and if instead of water, I made use of quick-silver, to half cover the egg, the cylinder of water would presently mount to the top of the pipe, and fall back again when the glass was taken out. Having, also, placed the vessel of quick-silver and basin of water near each other, and suffering the pendulous cylinder to ascend to its utmost height in the latter, I nimbly took it out, and plunged it into the former, where
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PHYSICS. the cylinder rose much higher; and the contrary happened upon removing the egg out of the quick-silver into the water; tho' the descent was neither so sudden nor great, as if the glass had been removed from the mercury into the air. At another time, when the weather was windy and rainy, the pendulous cylinder in the pipe sunk upon the immersion of the glass into water, both in the morning and afternoon; but not so much nor suddenly as in the preceding mornings.

2. *June 27*, in the morning, a small cylinder of water, suspended in the above-mention'd glass, immersed in water, immediately subsided to a considerable depth; but when plunged in quick-silver, presently ascended. Both parts of this experiment were often repeated. The reason of the phenomenon we suspected to be the warmth that the quick-silver had acquired by remaining all night in a chamber; whilst the water was fresh, and felt somewhat colder; and accordingly, in the afternoon, the water having also stood in the chamber, both that and the mercury would immediately, upon immersion, impel the pendulous water up into the pipe.

3. In the beginning of *January*, while the weather was frosty, we took up a few drops of water, as above, from a parcel set by, for a considerable time, to acquire the temperature of the air; and suffering the cylinder to remain long suspended, that the internal air might have the same temper as the external, we immersed the egg into a shallow vessel of the same water; whereby the small pendulous cylinder was suddenly impell'd upwards to the height of half an inch; when, the ball of the thermometer being taken out of the water into the air, it again slowly subsided. This was several times repeated, at intervals, in a close room, and with the same success, except that in the two last trials, when the thermometer was taken out of shallow water, and plunged deep into an adjoining parcel, the pendulous cylinder rose to twice the height it had done in the former; and when taken from this deep glass, and exposed to the air, it therein again descended to its low station.

I lay no great stress, indeed, upon these experiments, yet small-seal'd thermometers have given me cause to suspect that we receive different informations, as to the degrees of heat and cold in the air, by our organs of touch, and proper instruments. We may also allow, that not only water, but moist vapours in the air, will cause us to think it colder than the thermometer shews it to be. I, my self, have sometimes felt the weather more or less cold than the preceeding, when the contrary has appeared in that instrument; tho' no obvious circumstance, or alteration in my body was concerned. Nor cou'd this be the effect of any peculiarity in my constitution; for, upon inquiry, others have agreed with me in the reality of the fact. It might, therefore, be proper to observe the sense express'd by birds and other animals (whose diet is more simple and regular, and whose perceptions are commonly more delicate and less diverted than ours)

of

of the degrees of cold ; and particularly to examine the coldness of the air, and of other bodies, as well by experiments and instruments, as by the touch. *Martinius*, in his *Atlas Chinesis*, tells us "that the cold is greater in a certain part of *China*, than its latitude, of forty two degrees, " would induce one to expect ; for all the rivers, " says he, " are here of- " ten frozen for four months together, so as to bear horses, carriages, " &c. during which time, there's no sailing for ships ; and this hard " weather beginning about the middle of *September*, the ice is not " thaw'd before *March* ; for tho' the water be commonly froze thus " hard in one day's time, it requires a great many to thaw the ice. He adds, "'tis surprizing, the *Europeans* should remain unaffected " by this cold, and slight it as unable to produce ice in their quarter " of the world ; for which reason we must suppose subterraneous effluvia " to be the cause hereof." The common thermometer is, indeed, an useful invention, and the informations it gives us are, in many cases, preferable to those of our senses ; but we greatly over-value it, by sup- posing it an exact and perfect measure of heat and cold. Its contrivance is liable to several exceptions ; whence it becomes unapplicable in some cases, and improper in others. Besides, part of the liquor being here contiguous to the external air, 'tis apt to rise and fall, not only as heat or cold affects the included air, but according to the different weight of the atmosphere ; as both reason and experience assure us. Thus an ingenious physician found at the bottom of a very deep mine, that the water in a common thermometer, rose three inches higher than at the mouth thereof ; which, notwithstanding the usual warmth of such deep places, was owing to the additional pressure of a column of the air, equal to the depth of the mine below the earths surface. I have, also, frequently observed great variations to happen in the mercurial barometer upon considerable rains, fogs, or other remarkable and sudden altera- tions in the air ; and the same being likely to happen in the common thermometers, 'tis easy to mistake the rise or fall of the fluid they contain, for the effect of a greater or less degree of cold.

4. Two thermometers of a large division, and furnished with spirit of wine, one of them sealed, the air being shut up in its lower part, the other open, as usual, at top, being placed in a close room, the fluid in the sealed glass, regularly descended in cold weather, and ascended in warm ; and that with a small hole at the top, rose and fell with the other, whilst the atmosphere continued of the same weight ; but when that became greater, the liquor here stop'd short of the height where- to it would, otherwise, have mounted. On the contrary, when the at- mosphere grew lighter, the liquor rose higher in the open glass, than the increase of heat, alone, required ; so that by comparing these two thermometers together, I could, usually, foretel the height of the mer- cury in the *Terricellian* tube, and contrarywise, from the barometer, pre- dict the different ascent of the liquor in them. And once particularly,

Fig. 3. and 4.

Fig. 5.

PHYSICS. upon a considerable change of weather, which occasion'd a great fall in the barometer, I found the liquor in the open glass, risen seventeen divisions higher than that in the other, tho' they before stood nearly level; and comparing the height of each, with the mercury in the barometer, observed a week before, the fluid in the sealed glass had in that time descended five divisions, whilst the other in the open one, had ascended thirty one.

At another time, when the mercury stood higher than it had for a considerable while, whilst the weather was warm and clear, and the fluid in the sealed glass risen to fifty, that in the other was sunk to thirty two. From hence it is very possible, that an unregarded change in the weight of the external air, may compress that included in an open thermometer, more than a considerable degree of warmth can dilate it; and, consequently, common thermometers, which include air in their tops, contrary to the common opinion, may rise in warmer, and fall in colder weather.

If this wants farther confirmation, I might add, that, very lately, the mercury in the barometer, standing at twenty nine inches, and the liquor in the two above-mentioned weather-glasses, at nearly an equal height; upon the quick-silvers rising $\frac{1}{4}$ inch, the liquor in the sealed glass ascended to forty five, whilst that in the open one, descended below thirty five; that, upon the mercury's rising $\frac{1}{4}$ inch, the open glass sunk twenty three divisions, whilst the sealed one preserved its station; that, the same being risen to thirty inches, the sealed thermometer stood at forty one, and the other below nine; lastly, that the quick-silver continuing at thirty one inches, but the weather become much colder, the liquor appeared to have uniformly subsided in both glasses, standing in the sealed one at thirty three, but sunk in the open one quite below the bottom mark, which I thought impossible without frost; for having before observed the sealed glass to stand at thirty four, the other was no lower than forty one; whence I conjecture, that the additional weight of the atmosphere was the cause of this great difference; the quick-silver being now risen to twenty nine inches, and almost an half. To conclude, the last observations I made of this kind shew a greater variation in these glasses, than any hitherto mention'd; the former being that of forty five divisions: and the latter, being made upon somewhat a less exact glass than the above-mention'd, including air in its lower part; when the quick-silver in the barometer had ascended $\frac{1}{4}$ inch above its former station, the preceeding night, the tinged liquor, in the shank, that measured twenty inches, was, in no cold season, depressed above an inch below the surface of the surrounding fluid of the vial wherein 'twas plunged; whilst a bubble of the external air was seen to pass thro' the liquor, and join that contain'd in the vial. Such a difference is, doubtless, too surprizingly great to be alone attributed to the heat or coldness of the air.

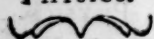
II.

We are greatly at a loss for a standard whereby to measure cold. The common instruments shew us no more than the relative coldness of the air; but leave us in the dark as to the positive degree thereof: whence we cannot communicate the idea of any such degree to another person. For, not only the several differences of this quality have no names assign'd them, but our sense of feeling, we see, cannot herein be depended on; and thermometers are such very variable things, that it seems morally impossible from them to settle such a measure of coldness as we have of time, distance, weight, &c. There are many degrees of coldness between lukewarmness and freezing cold, which we cannot express in words; and even the terms here used are very indefinite: for what to one is lukewarm, will be judg'd hot by a second, and perhaps cold by a third; and we find that different fluids, as oil, water, and wine, or even liquors of the same denomination, as different kinds of water, manifestly freeze more easily one than another. And, perhaps, the mildest degrees of cold suffice to turn some waters into ice; so that the differences of scarce any quality want names so much as those of cold.

Observations upon the defects of thermometers; and the sealed kind of that instrument considered.

Whoever makes many observations with a thermometer, is so confin'd to that numerical glass, that any one of those numerous accidents, whereto 'tis expos'd, would, tho' he retriev'd his instrument, reduce him to find a new standard whereby to measure the varying temper of the air: not to mention how exceeding difficult it is to include any fluid body, instead of air, in one of these glasses, fit to shew the alterations in the atmosphere, without receiving impressions therefrom in its first admission. Tho' I have sometimes consider'd whether the essential oil of aniseeds might not, during a considerable part of the year, be of use in the making and judging of thermometers; for this substance having the property to remain congeal'd at all times, when the weather is moderately cold; if by being thaw'd, and placed round the ball of the thermometer, furnished with rectified spirit of wine, and there suffered to congeal again of it self, the height of the spirit of wine be observed, when the oil begins to curdle; this may assist towards making another thermometer like the former: for if the like spirit of wine be placed in an equal and similar glass, a few careful trials made with this oil, thaw'd and congeal'd again, might bring the second glass to a similitude with the other. And if the quantity of the spirit be known, an estimate may be easily made, by the height it reaches in the neck of the instrument, of a known capacity, to what part of its original bulk it contracts. By means of the same oil, a conjectural estimate might also be made of the difference between two thermometers unequal in magnitude. 'Tis true, there are many ob-

PHYSICS.



jections to be made about the uncertainty of this method, proposed as a standard for weather-glasses; yet it may be of some small service in comparing and making these instruments. Another attempt to answer this end is, by observing the coldness requisite to begin the congelation of distill'd water: but the accuracy hereof is as questionable as the former; and 'twill often be found impracticable, even in the winter: 'tis also troublesome, but may prove successful, when the cold is sufficient to freeze water.

Fig. 6.

But to leave this difficulty, which seems almost insuperable, we may observe avoidable inaccuracies in measuring cold by thermometers. The stems employ'd herein are not always sufficiently even and cylindrical; but generally widest near the bubble: and a proper proportion might be observed between the bore and the spherical part, which wou'd greatly increase the certainty and usefulness of the instrument. Those where part of the liquor is exposed to the external air, might be much better contrived, at least for particular purposes, than what are commonly used; some whereof I have myself employ'd, that were made by inserting the end of an open cylindrical glass tube into a vial, and closing its mouth with cement, to prevent a communication between the external and internal air, except by the pipe. By this means, if you make choice of a large vial and a slender cylinder, the rise and fall of the liquor employ'd, will be several times greater than in the ordinary glasses, where the air is confin'd in a much narrower space. These glasses not only allow of larger divisions, and require no frames, which are considerations I here neglect, but are well fitted for many experiments, as we shall see hereafter on liquors and other bodies; they being easily applicable hereto: and thus not only the coldness of fluids, but of earth, snow, powder'd ice, &c. may be measured, by burying the vial in each respectively.

Again, 'tis generally concluded, that if the coldness of the weather causes the thermometer to rise, for example, one inch to day, and another to morrow, the air is twice as cold on the second day, as it was on the first; but the truth hereof seems very questionable: for tho' cold be allow'd to contract the air, yet it does not from hence follow, that a double degree of cold will cause a double condensation in the air. For not only the different quantities of the included air in several instruments, the different capacities of the pipes, and degrees of the air's expansion, when included, render this hypothesis very suspicious; but the condensation of the air, and ascent of the liquor, chiefly proceed from the pressure of the external air; and the power required to compress air is, in a reciprocal proportion to the space wherein it is included; so that, for instance, if the resistance of a four inch cylinder of air, be, when compress'd into two inches, a ballance for ten pound weight; an additional force equal to the former, will force it into the space of an inch; whence, the condensation of the air in thermometers

mometers must be estimated by the proportion that the space it deserts bears to the whole it before possess'd; regard being also had to its former degree of density. Nor must the resistance of the included air be look'd upon as that of a weight, continuing always the same, but that of a spring, forcibly bent, which attempts to restore its self in proportion as it is compress'd.

The particular nature of the liquors employ'd in thermometers will also claim our regard, till the theory of cold becomes more perfect; for tho' of two fluids, the one is more disposed to freeze than the other, the latter will not therefore be less susceptible of the lower degrees of cold than the former: the thermometer made with spirit of wine much sooner receives impressions from a faint degree of coldness, than those that are made with water. Moreover, we cannot always be certain, that the more subtile and spirituous liquors are least subject to congeal or lose their fluidity; for the chymical oil of aniseed, a very subtile strong and heating liquor, is more easily froze by cold than common water, and will remain in that state for many days after ice is thaw'd into water again. There are, also, other distill'd liquors, whose particles, tho' vehemently agitated, and excessively pungent on the tongue, and in these respects, perhaps, not inferior to *Aqua fortis*, may be congeal'd by a far less degree of cold than wou'd freeze the common chymical oils, or saline spirits. And till the nature and causes of cold be better understood, 'tis not absurd to imagine, that tho' some bodies seem fitted to produce this quality indifferently in all the substances they invade; yet if the refrigeration of a body be only the lessening of the agitation of its parts, there may be peculiar frigorific agents, besides those corpuscles that seem to be the universal efficient of cold, for particular bodies. Thus mercury is congealed by the steams of lead, tho' these appear to have no such effect upon any other fluid; and tho' such a degree of cold as will freeze water or wine, will not deprive quick-silver of its fluidity. And by the preceding relation of *Martinius* it appears, that water itself, in some countries, may, by the nature of the soil, be so disposed as to receive strange impressions of cold in proportion to the effect, which a particular degree thereof there has upon human bodies. And opium, three or four grains whereof will destroy the heat of the whole mass of blood in a man, does not, as far as I cou'd find by a good seal'd thermometer, sensibly refrigerate water; which seems to argue, that as different liquors have their peculiar texture, so certain bodies may, by the mechanical affections of their particles, be qualified to hinder the agitation of the parts of a particular liquor, into whose pores they insinuate, without having the like effect in other liquors of a different texture. What confirms me the more in this conjecture is, that I know some liquors, which will instantly congeal, even highly rectified spirit of wine. And the same I have, also, effected in other

PHYSICS.

other fluids. 'Tis true, in these experiments a congelation seems to be produced without any great additional coldness; yet I may here say, that by adding a particular substance, that wou'd scarce sensibly refrigerate common water, I can communicate a considerable degree of coldness to a particular fluid, which, to the touch, seems nearly of the same temper with water.

The sealed weather-glasses, which I first introduced in *England*, are, in several respects, preferable to the common sort. I found, indeed, some difficulty in bringing it to be allow'd, that a liquor hermetically sealed, wou'd rarify and condense, tho' some experiments assured me thereof; and I afterwards gain'd sight of a small thermometer brought from *Florence*, which farther convinced me of its possibility: but to fill the longer sort, is a task exceeding nice and difficult. The pressure of the atmosphere, which greatly disturbs the common kind, is prevented in these, which may therefore be used with equal success in any place, how high or deep soever. Neither is the liquor they contain liable to evaporate, or to be spilt in carrying: they may also be safely let down into the sea, or immers'd in any kind of fluid. The liquor employ'd in them, is highly rectified spirit of wine, tinged of a fine red with cochineal, open'd by volatile spirit of urine; so that we thus render it very conspicuous, secure it from freezing, and keep it susceptible of the slightest impressions from without; and 'tis surprizing to see how many inches high the liquor will rise in the cylindrical pipe of this useful instrument, by means of a small degree of heat. We are the more particular upon this kind of thermometer, because we shall hereafter make frequent mention thereof. But a philosopher will not rely so much upon them, as to neglect searching after other more certain methods of measuring the degrees of cold, than either these or our senses afford; for this instrument is not exempt from the imperfections formerly mention'd. And tinged spirit of wine, being a particular mixture, 'tis possible, the subtle effluvia of some bodies may get into it thro' the pores of the glass, which are permeable to the effluvia of the load-stone. To countenance this conjecture, I shall relate an odd phenomenon, which I observed since I began to write this history. Examining the temper of a strange mixture, (to be particularly mention'd hereafter) with one of our sealed thermometers, by burying its ball and part of the stem therein; whilst to the touch it seem'd only lukewarm, the liquor was slowly impell'd to the height of nine inches in a tube, but little above a foot in length; when, the instrument being removed from thence into a deep glass of cold water, out of which we took it, to make the foregoing experiments, the tinged spirit did not attempt to subside, but continued within half an inch of the very top of the thermometer, tho' it appear'd no where discontinued by any bubble of air, which might have been occasion'd by the warmth of the mixture. But what was still more surprizing,

prizing, tho' the instrument continued for four or five hours in the cold water, and some others exposed to the air, the tincture sunk not above half an inch; nay, tho' the glass were let stand for a whole night in the window of a close room, the liquor had not sensibly descended in the morning. Hence even seal'd thermometers, furnish'd with highly rectified spirit of wine, may sometimes be affected by peculiar agents, that appear not to be the genuine effects of heat and cold.

Orthelius tells us, that a liquor distill'd from the ore of bismuth, will considerably swell in the including glass at the time of the full moon, and shrink at that of the new; but having never been able to procure this ore, I can neither consult nor confirm so strange a phenomenon. *Casatus*, indeed, makes mention hereof, but not from his own observation. This however brings to mind, that I have made a tincture of amber, with highly rectified spirit of wine, which did, for many months, tho' kept in a well-stop'd glass, manifest certain changes, suspected to proceed from some secret alterations in the air, which here operated more remarkably than ever I had observed upon any liquors wherein spirit of wine abounded. And, perhaps, by careful observations, long continued, upon thermometers fill'd with various liquors, and kept in the same place, a difference wou'd appear between them, that cou'd be attributed to nothing so properly as the peculiar nature of the several fluids, which might be variously tinged by copper; as supposing *Aqua fortis*, *Aqua regia*, spirit of urine, spirit of sal-armoniac, or oil of turpentine employ'd herein. But that sealed thermometers, fill'd with spirit of wine, may be affected in a different manner from what is usually imagin'd, appears from the bubbles, which, after some time from their making, have emerged therein, and possess'd the space of several inches in the shank of the longer sort. And if these bubbles be small, and lurk between the spherical and cylindrical part of the glass, they easily pass unheeded, and prevent the spirit from moving according to the changes of the weather; for such a bubble is more indispoused than the liquor, to rise and fall in the slender tube. Hence it might be worth while to make collateral experiments and observations, to rectify or confirm the thermometer, in the notices it gives us of cold; and perhaps a careful enquiry might procure us several other bodies, either natural or factitious, for this purpose. Thus, tho' water, for instance, be thought the most apt fluid to freeze, yet we have distill'd a substance from benjamin, that will both congeal and thaw much more easily than that. Thus, also, I have observ'd a solution of amber-grease, made with spirit of wine, in sulphureous or resinous tinctures, and other chymical liquors prepared from urine, hartshorn, &c. wou'd sometimes shew perfectly clear, and at others, suffer a greater or less proportion of the imbibed substance to fall to the bottom, or crySTALLIZE, according to the alterations in the weather, as

PHYSICS.

to heat and cold. But, to return to water, 'tis observed that the rivers in some parts of *France* will sustain boats heavier loaded in the winter than in the summer; and sailors have inform'd me, that their ships draw less water upon the coasts of frozen countries, than in the *British* seas; which shews water to be heavier in winter than in summer. The like difference is, also, observable in water at different times of the day, according as the air is then colder or warmer; for having nicely pois'd a glass bubble, hermetically sealed, to float any where in water in the morning; it would about noon, when that fluid was rarified by the heat, sink to the bottom, and at night gradually rise again, so that by the next morning 'twas usually emerged to the top; and at other intermediate times of the day, it would, frequently, continue swimming up and down, between the bottom and the top, without reaching to either of them. Upon the whole, as by reason of the various and unheeded predispositions of our bodies, the immediate informations of our senses, are not always to be trusted as to the degrees of cold; so the common thermometers are useful instruments, and, in most cases, preferable to our touch, being less subject to unregarded changes than that sense; yet as these instruments are affected by the different weight of the atmosphere, as well as by heat and cold, they may easily, in several cases, give us a wrong intelligence, unless the pressure of the atmosphere be, at the same time, observed by other means. The sealed glasses are far superior to these, and, in particular, are not subject to the external pressure of the air; so that they here deserve to be depended on more than any other instrument hitherto discover'd; yet in cases of nicety, other methods of examining the coldness of bodies should be used. And in the last place, we ought not to be discouraged from making various experiments, with relation to the measure of cold; tho' they seem contrary to the vulgar notions thereof: for our theory of that quality is very defective, and ill grounded. I should never have attempted to make sealed thermometers, if the popular notions of a *Fuga vacui* causing water to be suspended in glass tubes, and of air being much easier condens'd by cold than any other liquor, had prevail'd with me.

III.

The cause of
the air's con-
densation con-
sidered, with
the ascent of
water, by cold,
in the common
thermometer.

'Tis certain that the most obvious phenomena of common weather-glasses have not been hitherto sufficiently examin'd. There are three remarkable opinions as to the reason why the liquor of this instrument, ascends with cold, and descends with heat; the first whereof is that of the schools, which supposes the cold of the external air to contract that included in the glass, and reduce it into a less compass than before; whence the water necessarily ascends to fill the vacuum. But this, we see, is not the case in the *Torricellian* tube; for the mercury here remains

remains at about the height of thirty inches, without attempting to rise and fill the void space at the top. And in sealed thermometers, the air seems rather to expand, than shrink in cold weather. The second opinion is that of Mr. *Hobbs*, when he says, "fluid bodies are made colder by the pressure of the air, that is a constant wind that presses them:" but we shall see hereafter that water will be froze, tho' sealed up in glass vessels, suspended in others, and wholly immersed in unfreezing liquors; so that the water could by no means be raked with the wind, as Mr. *Hobbs* fancies. Besides, there's no necessity for a wind to press the water up into the shank; since it will rise in a still place without the assistance thereof. But besides the deficiencies of this hypothesis, we find, by experience, that water, poured into a bolt-head till its ball, and large part of the stem be filled, will shrink by a degree of cold that falls short of freezing, instead of rising higher; and if a mixture of ice, or snow and salt, be applied to the bottom of a common thermometer, the water will be thereby made to ascend several inches in the stem. Lastly, Mr. *Hobbs* supposes the water in thermometers to descend merely by its own gravity; but this alone cannot, in some cases, serve the purpose, without the assistance of the spring in the included air: for if a thermometer with a large ball, be placed in a window exposed to the sun, the surface of the water in the tube, will often appear considerably below that on the outside thereof; and consequently this depresso proceeds not from the bare gravity of the fluid, but from the pressure of the incumbent air. And for a farther proof hereof, if you keep such a glass long enough in the sun's heat, the water will be driven out of the shank, and forced thro' that which is external to it, in bubbles; when, if the remaining air be again cooled, by setting the glass in a place less heated, the loss of the air that escaped in bubbles, will permit the water to ascend higher in the shank, than the same degree of cold would have before impell'd it. Thus much may suffice to shew the erroneousness of Mr. *Hobbs*'s notion.

The third opinion is that of some ingenious moderns, who account for the ascent of the water in weather-glasses, by the weight of the air; for the coldness thereof, say they, causes the included air to shrink into a less compass; whence the water in a subjacent vessel, is, by the weight of the incumbent air, (which presses more forcibly upon all the other parts of its surface, than upon that included in the shank) impell'd into the part deserted by the contraction of the air. But this solution, tho' ingenious, and true, and preferable to both the former, still appears insufficient; tho' if we add hereto, the pressure and spring of the external air, not only against the surface of the water, but also that of the included air, it will fully account for the phenomenon: for the pressure of the continuous air appears remarkably concern'd in contracting that shut up in the glass; the ambient air retaining its

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whole

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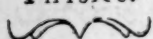


Fig. 6.

whole pressure upon account of its weight, whilst the internal, by being cooled, loses part of its pressure, by reason of its weaken'd spring. In some cases it may, also, happen that the air, which supports the water to be raised, will be less cold than the included, that is to be condensed; whence the former will have a stronger spring, and consequently a greater pressure than the latter. The following experiments countenance this solution. 1. Having almost half filled a six ounce vial with water, we inverted thereinto a slender glass pipe, ten inches long, sealed at one end, and filled full of water by the other, which was immersed, so that no air remained at the top of the tube; when, the neck of the vial being well cemented, we plunged the bottom of the instrument in snow and salt, till the included water began to freeze both at the top and bottom: but the water in the pipe did not descend; so that either the air never shrunk, by so great a degree of cold, or the water did not remove out of the pipe to possess the place deserted by the cooled air. We afterwards attempted to repeat this experiment in the same instrument, but the sealed part of the tube being broke in our absence, (by the swelling, as we supposed, of the water, upon freezing,) prevented us.

2. We, therefore, fasten'd into the same vial, a pipe some inches longer than the former, but drawn very slender at the sealed end; when, having set the vial to freeze, as before, without finding the water descending in the tube, we broke off the sealed end, upon which the water was swiftly depress'd to the depth of ten inches; but so that it yet continued considerably higher than the surface of the water in the vial. After this, by rarifying the air in the vial, and blowing into it thro' the pipe, the water rose, almost, to the top of the tube; the slender end whereof being sealed, the vial was again placed in snow and salt: but the spring of the rarified air at the top, was so weakned by the refrigeration, that it could not sensibly depress the water; wherefore breaking off the sealed apex, as before, the external air immediately sunk it several inches.

3. For a farther experiment we left, in the same pipe, about $3\frac{1}{2}$ inches height of air very slightly rarified; when, again, placing the vial in salt and snow, we observed that the air in the pipe expanded it self very little, upon the refrigeration of that in the vial, tho' the water in the vial were considerably froze; but upon breaking the sealed end, the external air presently depress'd the water above two inches below its last level: and removing the glass into a warmer room, the water ascended above an inch higher than the same uppermost level; whence we, with some probability, concluded our thermometer stanch.

Fig. 7.

4. Having poured a proper quantity of water into a glass, resembling the bolt-head of a common thermometer, except that its small end was drawn very slender, which we hermetically sealed; and inverting the glass, the water fell to this end, and possess'd its due space in the pipe.

To

To the round end of the glass, we then applied a mixture of snow and salt, whereby, tho' the internal air was, doubtless, greatly refrigerated, yet the water did not manifestly rise; and if it had, that might very well proceed from an expansion of the aerial particles which usually remain in common water, occasioned by the diminished pressure of the air above the surface of the water, whilst the spring of that air was weakened by the cold. But, to compleat the experiment, breaking off the slender end of the glass, under water, (whereby the included air became contiguous to water, which immediately communicated with that, whose surface was every where press'd by a column of the external air incumbent thereon,) the water was suddenly impelled into the pipe, to the height of several inches.

5. We procured several glass bubbles of various sizes, each of them furnished with a long slender stem, whereinto we conveyed a drop or two of water, which was there kept suspended, so as to manifest the smallest changes in the rarification or condensation of the air, whereto it was contiguous. Now when the pendulous water here, approached near the top of the stem, we could, in an instant, with the flame of a candle, seal up the orifice thereof; and when, having done thus, we placed the glass in salt and snow, yet the pendulous water nearly preserved its station. But if, with a pair of scissars, the sealed end were dextrously snipp'd off, the water would be swiftly forced down, sometimes many inches below its former station, and sometimes quite into the round end of the glass. We farther observed, that, not only when these thermometers were sealed, the usual degrees either of cold or heat in the air would not, considerably, affect the pendulous cylinder, tho', if left open, they shew'd, as we said before, the minutest differences hereof; but we several times, suddenly, sealed one up, whilst the pendulous water was descending therein, whereupon its motion would immediately stop in that part of the shank where it chanced, at that time, to be; and the fluid wou'd there continue till the sealed end were broken off.

6. We took a large glass egg, with a long stem, bent in the form of a siphon, whose shorter leg was drawn small, and poured a convenient quantity of water into it, which ascended to a considerable height in both legs; after which, the short one was expeditiously sealed, while a tolerable quantity of air remain'd above the water it contain'd, to impel, by its spring, the water into the longer, upon the refrigeration of the air included in the latter. This done, we placed the whole glass in a convenient frame, so that the oval part was supported thereby; whilst underneath hung the bended shank of the glass in such a manner, that a mixture of snow and salt might be laid upon the frame, to surround and cool the air, included in the egg, without much affecting that in the cylindrical part of the glass; and upon the application hereof, for a proper time, the water in the longer leg ascended, and the air in the shorter, rarified a little: but as soon as

Fig. 8.

PHYSICS.

the slender wire, wherein the shorter leg ended, was broke off, the external air, rushing in, caused the water to rise above $2\frac{1}{4}$ inches in the longer leg, and then, there not being water enough, broke through it in many bubbles. In which case, the ascent of the water in the longer leg, cannot be attributed to the weight of the air in the shorter, because it is vastly too small for that purpose; but to the spring of the same. And 'tis not surprizing, the expansion of that air should be so small, since, as we shall see hereafter, the refrigeration of the air, in such experiments, is very inconsiderable; whence the air in the longer leg cou'd yield but very little to that in the shorter.

From what has been hitherto offer'd, it appears, that the business of thermometers is, at present, but very imperfectly understood; and that farther experiments and observations are required to settle this affair.

IV.

*Experiments
with bodies
capable of
freezing o-
thers.*

All sublunary bodies, fire alone excepted, are perhaps, at some time or other, susceptible of actual cold; at least if our senses were to judge: and even as to fire itself, the point must remain undetermin'd, till we know whether that be a particular state of matter, as wind, for instance, is, or else a species of natural bodies; for some substances, as gun-powder, are instantaneously turned into fire; and others, as spirit of wine, are wholly inflammable, tho' before ignition they were sensibly cold, nay gun-powder, if its scatter'd parts be collected in a close vessel, will, immediately after explosion, give the sensation of coldness. But our design is here not to engage in nice questions, but to deliver the phenomena of congelation.

1. There are but few bodies capable of freezing others, in our climate; and among the most remarkable, is a mixture of snow and salt, which, tho' little used in *England*, is frequently employ'd in *Italy*, and other countries, to cool their liquors and fruits, by immersing them therein.

2. We cou'd not find, upon several trials, that such glasses of water as were easily froze by this mixture, wou'd be so by snow alone. 'Tis possible, indeed, in very cold countries, that both snow and beaten ice may freeze water poured in the interstices of their parts; but there's a wide difference between this case, and only surrounding a vessel of water with the mixture: and perhaps the ice and snow of frigid climates may have a greater degree of coldness, than they have in *England*. And tho' a vessel of water, buried all night in snow, shou'd freeze, the effect must not be wholly attributed to the snow, if the coldness of the air wou'd, alone, have produced it, and did at all contribute thereto.

3. 'Tis not only sea-salt that added to snow, will increase its freezing faculty; for several other things have the like virtue: nitre, alum, vitriol,

ol, sal-armoniac, and even sugar, may here be substituted for common salt, tho' not, perhaps, to equal advantage.

4. Spirit of salt, tho' it suddenly dissolves snow, yet, upon account of its fluidity, cou'd not, in the usual manner, be detain'd long enough thereon to freeze even a very small quantity of water.

5. We, therefore, put some snow into a thick, green, glass vial, and mix'd with it a proper quantity of weak spirit of salt; then, stopping the vessel, we shook them well together; yet the glass appear'd only bedew'd on the outsides, without exhibiting any thing frozen. But suspecting the thickness of the glass might hinder the effect, we put the like mixture into two thin vials, one whereof was firmly closed, and the other slightly; when, having long shook them, we found what adhered to their outsides thinly frozen.

6. Let it be here observed, that in this kind of experiments, the snow or ice, included with the saline ingredients, was always thaw'd within the glass; and that, consequently, it must be the condensed vapour of the air, or other liquor which adhered to the outside thereof, that turn'd to ice: and for this reason we frequently use the word freeze, for the operation of the frigorific mixture, here applied, upon other bodies.

7. Upon mixing snow with oil of vitriol, in such a vial as the last mention'd, we found its freezing power much greater than that of spirit of salt. And to shew that, in these experiments, the cold was transmitted thro' the sides of the glass, and that the air included, being greatly cooled by the mixture, did not by communication enable the air contiguous to the outside of the vial, to freeze the dew thereon; we several times sealed up the containing vessel, and afterwards froze, by means of this mixture, the external moisture.

8. Spirit of nitre, we observed, froze more strongly than either oil of vitriol or spirit of salt, and continued this virtue till the included snow, that lay opposite thereto, was almost wholly dissolved: and this we experienc'd, not only in a thin, sealed glass, but also in a tolerably thick one, stopp'd with a cork.

9. We afterwards successfully made the experiment with spirits less acid, as that of vinegar, and the red empyreumatical one of sugar; but the films of ice, with the latter, were very thin, and apt to vanish.

10. Urinous volatile spirits were next made use of. Spirit of urine and snow being agitated in an open vial, discernably froze the external moisture; but with spirit of sal-armoniac, *cum calce*, the effect was quick and strong.

11. Acid and volatile spirits having been tried apart, we also try'd them in conjunction. Pouring some spirit of urine and oil of vitriol upon snow, and shaking them together in an open vial, the mixture did freeze, tho' very faintly.

12. Some

PHYSICS.

12. Some trials also were made with the grosser salts, as *Sal Gem*; a sublimation of sal-armoniac and common sublimate, sugar, &c. with all which, the experiment succeeded. A very strong solution of potashes, also, mixt with snow in an open single vial, froze, tho' faintly; and a solution of pure salt of tartar, managed in a like manner, produced thin films of ice.

13. Having fill'd a single vial with snow, we poured thereto a proper proportion of a very sweet solution of *Minium*, made with spirit of vinegar; when, shaking them together, we found films of ice on the outside of the glass; tho' a parcel of the same solution, kept for several hours in snow and salt, was not thereby frozen. In search of the cause whereof, we sealed up a single vial of pure snow, which thaw'd much more slowly than any of those parcels wherewith salts or spirits had been mix'd. And so far as my observation reaches, no salt, that promotes not the dissolution of snow, will enable it to produce ice, tho' it causes dew on the outside of the containing vial; thus, neither crystals of tartar, nor borax pulverized, nay, nor sublimate, wou'd dispose snow to freeze, but lay, for a considerable time, undissolv'd therein.

14. Lime-water, twice tried, wou'd not make snow freeze; but this liquor was above a year old, whence probably its spirit might have evaporated. But all the vials that froze not, collected store of dew, which I attribute to the sole melting of the snow.

15. Nor wou'd distill'd oil of turpentine cause snow to freeze.

16. Sealing up a convenient quantity of pure spirit of wine in a vial, almost fill'd with snow, we observed the freezing virtue of the mixture to be greater than any hitherto mention'd; its effect was also lasting, and that too in another vial that was left open; but the sealed up parcel, crufted over the outside of the glass with ice, which we took off in flakes of a considerable breadth and thickness; nay, it immediately froze urine into figured ice, that might be scraped from the glass.

17. Happening to mix snow with a lucky proportion of spirit of nitre, it froze with that suddenness and vigour, as, in an instant, to fix the vial to the floor 'twas set on; when, bedewing the outside of the glass with spirit of vinegar, it froze into tolerably thick ice, retaining the salt tast of the spirit. This mixture, indeed, wou'd not discernably freeze spirit of nitre on the outside, tho' it did a weak spirit of salt, and presently turn'd other saline liquors into figured ice, representing small circles crossing each other, and suddenly vanishing. Spirit of sal-armoniac, made with lime, was also congealed hereby, whereupon it shot into branches, almost like those of sal-armoniac, or the like undistill'd salts dissolv'd. And it was pleasant to see, how, upon inclining the glass to let the freezing mixture rest near any part of the spirit, the liquor wou'd suddenly shoot into ramifications, so that the eye

Experiments and Observations upon Cold.

591

PHYSICS.

eye cou'd plainly discern them to grow, as it were, and soon overspread the surface of the glass, and then presently vanish. Several undistill'd fermented liquors being, also, applied to snow, instead of spirit of wine; the experiments succeeded not with small beer, but wine and moderately strong ale produced a slight ice.

18. Observing that whatever hasten'd the dissolution of the snow, generally promoted its freezing, 'twas thought proper to try what wou'd be the event of suddenly dissolving snow by bodies actually warm. Into a single vial almost fill'd with snow, we poured a tolerable quantity of heated sand, to dissolve the snow in many places at once, without heating the external air, or the outside of the glass; and tho' the solution of the snow was hereby promoted upon shaking the vessel, yet the outside of the glass was only bedew'd, not frozen.

Into another vial almost fill'd with snow, we poured warm water, that it might fall upon the middle part thereof; then taking a convenient time to shake the glass, we, by this means, produced a very considerable degree of cold, and much dew on the outside, but cou'd not be certain it was frozen; tho' the experiment deserved to be repeated.

19. 'Tis a popular opinion, that the hoar-frost, visible upon glass windows in a frosty morning, is an exudation of the glass, condens'd and froze into various figures, by the cold external air. But the ice lies not on the outside, but inside of the windows, where 'tis generated of the watery particles floating in the air of the room, and by their proper motion passing along the surface of the glass, where they are, by the vehement cold of the adjacent, external air, communicated thro' the glass, condensed into dew, and frozen into ice.

20. Many modern naturalists hold, that glass is easily pervious to air, and several subtiler liquors, who may, therefore, assert that the ice in our experiments proceeds from the fine parts of the cold mixture passing thro' the pores of the glass, and settling on the outside thereof. But the following experiments will shew the falsity of this doctrine.

21. A mixture of ice and salt, weighing four ounces and a quarter, being included in a vial, and condensing the vapours of the external air, thereby increased its weight twelve grains. Another vial of snow, that weighed two ounces, six drams, and a half, by condensing the vapour of the external air, augmented the weight of the vial and its contents four grains; and in the scale, we found the water flowing from the dew, which gave this increase of weight. The tip of this sealed vial being broken under water, a considerable quantity of that fluid was drawn in; whether upon account of some small rarification of the included air, caused in the sealing, or of its coldness receiv'd from the snow, or both together, I shall not now inquire.

22. Others

PHYSICS.

22. Other experiments were made, wherein this increase of weight was more considerable. We sealed up as much snow and salt, in a single vial, as, being afterwards melted, weighed between five and six ounces; and the solution beginning to be made, the dew on the outside began to congeal, and when rubbed off, the hoar-frost would presently appear again. We next ballanced this glass in a pair of scales, when, as the external vapour of the warm room condens'd to its sides and froze, the scale containing the glass sunk gradually lower; but by adding weights in the other, we again reduced them to an equilibrium; tho' the former would soon after descend; till the included snow was thaw'd; so that the whole weight required to bring the balance even, was about eight or ten grains. The vial being then taken out, there appeared near half a small spoonfull of liquor in the scale wherein it stood, occasioned by the thaw of the ice generated on its sides; but no moisture appear'd in that part of the scale that was covered by the convex part of the bottom of the glass.

23. A like quantity of snow being sealed up with spirit of wine, in a single vial, the outside was presently cas'd with ice to the same height that the mixture stood within: this vial also was counterpoiz'd, and sunk as the former, and about seven grains were required to reduce the ballance to an equilibrium.

24. When the experiment happened to be more luckily made, this increase of weight was still greater. At one time, when the mixture of snow and spirit of wine weighed three ounces and three quarters, it afforded eighteen grains of condensed vapours. At another time a mixture of snow and sal-gem, that weighed three ounces and seventy grains, gave an additional weight of twenty grains of water.*

V.

Experiments
and observa-
tions upon bo-
dies disposed
to be froze.

1. Different bodies will freeze with different degrees of cold; but it were endless to try, particularly, what substances are capable of congelation, and what not: but not to leave this part of our history untouch'd, we shall mention a few.

2. In very cold snowy weather, we observed water, urine, bear, ale, milk, vinegar, French wine and Rhenish, to be either wholly, or in part, converted into ice, tho' the two last but slowly. We also froze a

* Something like these experiments, whereby a great degree of cold is produced, seems to be done by nature in a cave, in Franche County, fifteen miles from Besançon to the East. In this cave it is excessive cold in summer, and proportionably colder as the weather abroad is hotter. For the place abounding in nitrous salt, or sal-

armoniac, and especially the top of the cave, the heat of the summer putting this salt in motion, it mixes and unites with the water that runs down the sides and clefts of the rock into the cave, and there congeals into ice. *Hist. de l'Acad. A. 1712. p. 27.---29.*

strong

strong solution of gum-arabic and white sugar, made in common water; and exposed to the cold air, the like solutions of alum, vitriol, salt-peter, sea-salt and verdigrease in single vials: those made with the alum, nitre, and verdigrease, froze without any remarkable phenomena; in that of vitriol there remain'd, at the bottom of the glass, a considerable quantity, clear and unfrozen, the colour whereof shew'd it to be greatly impregnated with the vitriol, while the upper part of the same differed little in colour from common ice.

3. Not only these grosser saline bodies were thus exposed, but also such as had been refined by fire. Spirit of vinegar, and spirit of urine, being exposed, in separate glasses, to an intense cold, we observed them both to be frozen.

4. To two ounces of water we added a dram of the fiery lixiviate salt of pot-ashes, and exposed them to a very sharp air; when coming to examine the success, we found little sticks of ice upon the top, like the crystals of rock nitre, whilst others shot downwards in great numbers.

5. Oil of tartar *per deliquium*, tho' it seem'd greatly to resist the cold, was, notwithstanding, once brought to congeal by snow and salt.

6. As to the freezing of common express'd oils, I know not what to determine. That they may, by a very intense cold, be deprived of their fluidity, so as to be cut into portions of any figure, my own experiments persuade me. But whether they are convertible into real ice, is a question undeterminable by any trials we could make in *England*. I am informed, by the *Russian* Emperor's physician, that oil in *Muscovy*, freezes much harder than with us; but will not there become perfect ice: on the other hand, Captain *James* tells us expressly, that in the Island where he once winter'd, "their oil, as well as every other liquid, was frozen so hard as obliged them to cut it with a hatchet." And *Olaus Magnus* relates, that "in the battles fought upon the ice, in the northern regions, the soldiers wear not leather, but woollen harness on their legs; because," says he, "the cold, in these parts, gives the slipperiness of ice to whatever is dress'd with oil." Common aniseed-water, and the like weak spirits, will, by the cold in *Muscovy*, according to the relation of the physician above-mentioned, be turn'd into an imperfect ice; and the stronger spirits into a substance like that of oil.

7. A solution of *minium*, made with spirit of vinegar, was, upon the 26th of *December* in the morning, tho' it stood near the fire, so strongly frozen, that part thereof appear'd shot into *Saccharum Saturni*; whilst a small quantity remain'd on the top unfrozen, of a yellow colour; which being poured out, did not congeal.

8. A solution of gold, made with salts, that stood with the solution of *minium*, was also frozen.

PHYSICS.

9. A quantity of the tincture of *Lignum Nephriticum*, that filled a pint vial, being froze, exhibited no colour in the ice, whilst it remain'd fluid.

10. Mr. *Drummond* informed me that he had often seen wine, and brandy, frozen in *Russia*; but that the ice of the latter was less hard than the common sort.

11. A *French* chirurgion told me he had several bottles of brandy frozen in *Russia*; whilst a liquid part retired to the center, and appeared to be spirit of wine, vastly stronger than common brandy.

12. The *Russian* Emperor's physician acquainted me, that on the 7th of *December*, having put some *French* brandy into a *China* cup, and exposed it to the air, it was, in three hours time, turn'd into a crusty ice upon the sides of the cup; and that exposing water and sallet-oil together, the latter was reduced to the firmness of tallow, while the former remain'd unfrozen.

Solid bodies
frozen.

13. As to the freezing of solid bodies, we have sometimes tried it by exposing wood, and branches cut off from growing trees, to an intense degree of cold, by which they seemed, in one night's time, to be, for some little depth, manifestly invaded by the frost. But a domestic of mine having, lately, felled an old apple-tree, on a day that had been preceded by a fortnights bitter frost, inform'd me, that he found the frost had pierced the very middle of it, tho' it was a foot diameter. And an experienc'd artificer in building, told me he had often seen, here in *England*, pieces of timber apparently frozen, and render'd exceeding difficult to be sawed; the frost also evidently continuing in the saw-dust. And, therefore, it will be the less strange if, in *Poland*, the effects of cold upon wood, be more conspicuous. A learned native assured me, that it was there usual to have wood frozen so hard, that the hatchets wou'd not cut, but rebound from it: he told me, also, that he had several times seen pieces of timber, which, having been thoroughly frozen in the air, and afterwards brought into warm rooms, were covered with a kind of hoar frost, which made them look white. He added, that his bow, which I saw, was very strong and tough, for it consisted of horn and other close materials, would be so changed by the frost, that unless special care were had in thawing of it, it would break.

14. That marle, chalk, and other less solid terrestrial concretions, will be shattered by strong and durable frosts, is observed by husbandmen, who find them thereby the better fitted to manure their land; the texture of those bodies being, by congelation, in great part dissolv'd: but that true and solid stones, such as are employed in noble buildings, should be spoiled by the frost, will, perhaps, seem very improbable; yet I have learned from a most ingenious and experienc'd mason, that he had often observed, both free-stone, and harder stones than that, to be exceedingly spoiled by the frost, and reduced to crack

crack or scale off, and thereby blemish and prejudice the houses built with them. But because it may be objected that some of the stateliest fabrics in *England*, chiefly consist of these stones, and yet very well endure the inclemencies of the air; we must observe, that the difference may not depend upon the peculiar nature of the stones employ'd, but on the several seasons in which they were dug out of the quarry. For if they be hewn out of the rock in cold weather, and employed in building the same winter, they will, upon very hard frosts, be apt to shatter or scale; but if dug early in summer, and suffered to lie exposed to the sun and air, during all the heat thereof, they will thereby be seasoned, and made able to endure many sharp winters unimpaired. It seems to me worth trying whether, during their lying exposed to the sun, they do not exhale a certain unripe mineral sap or moisture, which, remaining in the stone, may, by very piercing frosts, be congealed and shatter its texture. This seems agreeable to what an understanding person, who is master of a great glass-house, told me, of his great earthen pots, which are made up with as little water as possible, and thence become deservedly famous for their durable texture; for he assured me that if he did not take care to keep the frost from getting into them, those solid vessels wherein he used to keep his glass infusion, would, in the fire, scale, crack, or fly; and become unserviceable several weeks sooner than if they had never been impaired by the frost. He, also, affirmed that in very hard frosts several glasses that had continued intire for many weeks, would, as it were of their own accord, crack with a loud noise.

To this may be added, the testimony of an experienced *French* author, *Bernard Palissy*, who tells us, "that the stones of the mountains of *Ardenne*, are harder than marble; and yet the inhabitants of that country do not take them out of the quarry in the winter, because they are subject to the frost; and that it has often been found upon thaws, that the rocks, without being cut, have fallen down, and thereby killed many persons." It may seem far more unlikely, that frosts should get into metals themselves; yet the *Polonian* lately mention'd, assured me, that upon drawing his sword, or pulling out his pistols in a warm room, after he had been long in the field, he has presently found them almost whitened over by a kind of small hoarfrost. But if we credit *Olaus Magnus*, considerably thick pieces of iron and steel will, in the *Northern* regions, be rendred so brittle, by extreme frost, that they are there obliged to temper their instruments after a peculiar manner. And even here in *England*, I have caused trials to be made in very frosty weather, whereby, if an expert smith, I then employ'd, did not wilfully deceive me in the iron, that metal may, by such degrees of cold as even our climate affords, be rendered exceeding brittle: and he several times affirmed to me, that there are some kinds of iron which he could hammer and turn, as they

PHYSICS. phrase it, cold, in open weather, which yet in very hard frosts, would become so brittle as, by the same way of working, easily to break or fly asunder; and this he asserted both of iron and steel; as to the latter of which, another very skilful workman certified the like. And for further satisfaction about this matter, I enquired of a very dexterous artificer, well skilled in making springs, whether he found a necessity of giving them a different temper in very frosty weather; who told me, that to prevent their breaking in such weather, he was obliged to let them down lower than at other seasons; which makes it probable, that cold may have a considerable operation upon bodies where it is not suspected. And this affords a hint that may possibly reach further than we seem to be aware of; as to the share that quality may have in producing many phenomena of nature.

VI.

Experiments
upon bodies
indisposed to
be froze.

1. We found many distilled spirituous liquors, well freed from phlegm, which disposes bodies to congelation, could not be brought to freeze, either by the cold of the open air in frosty nights, or such an application of snow and water as served to freeze other substances.

2. Of this kind were *Aqua fortis*, spirit of nitre, spirit of salt, oil of turpentine, and almost all the chymical oils. Spirit of wine also, and of other fermented liquors, would not congeal; and even sack it self, if good, would scarce afford any ice at all. But after burning away some of the more spirituous parts of a quantity of this wine, that would yield no ice, the remaining portion was easily brought to freeze. Having exposed two drams of pot-ashes dissolved in one ounce of water, the vial that contained them was cover'd with hoar-frost and ice on the outside; but the mixture froze not a whit within. At another time, a very strong solution of salt of tartar kept fluid, whilst a tolerably strong solution of pot-ashes, that was exposed therewith, froze. These experiments, therefore, with lixivate liquors, shou'd be repeated, to reduce them to a certainty.

3. Train-oil, which is made, by the help of fire, from the fat of the whale, exposed twice or thrice in a vial to a very cold air, continued fluid; till at length, the night proving excessive cold, 'twas congealed the next morning. But what credit does this bring to the report of *Olaus Magnus*, who tells us, 'tis usual in the northern regions to fill up the frozen ditches of fortified places with train-oil, in the winter, to preserve the lower water fluid, and keep the enemy from passing them. 'Tis however worth enquiry, whether the whale-oil used by the *Swedes*, *Laplanders*, *Muscovites*, &c. be different from ours, unless *Olaus Magnus* maybe justly said to have often imposed upon his reader.

4. A strong solution of common sugar was easily converted into ice; but one of *Saccharum Saturni*, could not be thus alter'd by salt and snow; which is the more remarkable, because of the two ingredients

of

of this preparation, lead and spirit of vinegar, the former is allow'd to be a very cold body, and the latter has, by a like degree of cold to that here used, afforded ice. And as *Saccharum Saturni* is but a kind of vitriol of lead, 'tis remarkable, that its solution shoud not freeze, as well as that of common vitriol, when to make the latter, metal is corroded by a spirit probably much sharper and stronger than that of vinegar.

5. We, likewise, attempted to freeze quick-silver; and for that end, provided a thin bubble blown so flat, that its opposite sides almost touch'd each other, which, therefore, contain'd but a small quantity of mercury, spread out into a large surface, to receive the action of the cold: but our endeavours herein prov'd fruitless, tho' the last trial was made in the same intense degree of cold, with one of the following experiments. Having long expos'd another thin glass bubble of quick-silver to a vehemently sharp air, the cold had some small effect thereon, but wou'd not bring it to freeze; wherefore, I wish that the trial were made in *Muscovy, Greenland, Charles-Island*, or the most frozen regions.

6. 'Tis remarkable, that tho' solutions of many gross salts, and even the more saline and spirituous liquors, are, by snow and salt brought to congeal; yet a very strong brine of common salt never froze at all, tho' expos'd with other saline solutions, that were turn'd to ice, in an exceeding sharp night. But exposing a solution made of one part of sea-salt, and twenty of water, in a single vial, to the air of a very intolerable cold night, we on the next day found a great portion of the liquor frozen; the ice floating on the top in figures, resembling those of broom, and spreading downwards from the surface of the water. And, by the way, we permitted the ice of salt-water to thaw, in order to see whether it wou'd yield fresh; but it still retain'd some brackishness; which, whether or no it proceeded from the brine contiguous to the ice, I leave to be determin'd; being credibly inform'd, that the thaw'd ice of sea-water is often used in *Amsterdam* for brewing. And *Bartholine*, in his book *de Nivis usu*, confirms this relation, in the following words. "'Tis certain," says he, "that if the ice of sea-water be thaw'd, it loses its saltness; as has been lately tried by a professor in our university."

7. Spirit of sal-armoniac with quick-lime, volatile oil of amber, a little oil of vitriol, a solution of silver in *Aqua fortis*, some diluted rain water, and a vial full of weak spirit of human blood, were expos'd for two nights and a day, to the cold; whereby the three former were not at all frozen, but the solution of silver was congealed, and the spirit of human blood almost wholly converted into ice, which rose so high, as to thrust the cork out of the vial that contained it.

8. Unrectified oil of turpentine, tho' expos'd all night in a single vial, would not freeze; yet the same quantity, set in an earthen vessel, had its upper part turn'd to tolerably thick ice, figured almost like that of frozen urine.

PHYSICS.

9. A traveller inform'd me, that in a part of *Scotland*, there is a lake, from which issues a small river, neither of whose waters are ever froze in the depth of winter, which is there excessive sharp: he adds, that lumps of snow and ice, cast into the lake, do readily dissolve therein; and that this water differs not, in taste, from the common.

10. A commanding officer inform'd me, that his soldiers making use of sallet oil to the locks of their muskets, could not make them discharge; but being advised to apply hemp-oil, they froze not therewith: nor, as I am told, will train-oil freeze.

VII.

Experiments
and observa-
tions of the
degrees of cold
in several bo-
dies.

1. Having already treated of thermometers, and the methods of applying the nicer sort, to estimate the different degrees of coldness, both in solid and fluid bodies, we need only here farther add, that when they are used in consistent substances, we alter the figure of the round bubble into a flat bottom, that the whole instrument may rest thereon; due care being always had to take it up by the slender end, for fear of rarifying the included air: and thus it may be transfer'd, with a pendulous drop in the pipe, from one solid body to another.

2. To make a tolerable estimate of the difference between such high degrees of cold, as will all suffice to congeal water, is a difficult task; for freezing having been commonly reputed the ultimate effect of cold, men have seldom look'd beyond it. The difference between different frosty seasons are too manifest, and frequent, to be wholly ascribed to the different tempers of our bodies; yet how to estimate that difference, is not so obvious. The common weather-glasses, we have formerly seen, may easily deceive us herein. Some guess, indeed, might be made by the operations of cold upon liquors, yet some will freeze too suddenly, and others not at all in *England*.

3. Upon these and the like considerations, we thought proper to employ an expedient, the nature and use whereof will appear from the following experiments. And tho' a mischance prevented me from determining exactly, how much the spirit of wine in my thermometer was contracted, in proportion to its whole bulk, by the excess of cold, above what was necessary to freeze common water; yet something of use to the present subject may be thence collected: and particularly, the chief thing will manifestly appear therefrom; that is, the intenseness of cold, produced by art, beyond what nature necessarily employs, to turn water into ice.

4. We took a small sealed thermometer, furnish'd with spirit of wine, a ball about the bigness of a large nutmeg, and a very slender cylindrical stem, ten inches long; and immersing the ball and part of the stem in a vessel of water, half buried in snow and salt, the water began

gan to freeze at the top, bottom and sides, whereupon the tinged liquor subsided $5\frac{2}{3}$ divisions, which were half inches; then being taken out, and ice and salt immediately applied to the ball, the spirit fell $1\frac{1}{2}$ division lower. And that the water, tho' in part congealed, remain'd warm, in comparison of the spirit of wine, which was fluid, tho' refrigerated by the snow and salt, appears from the following experiment.

5. The glass continuing in the water till that began to freeze, descended to $5\frac{1}{2}$; when, being immediately removed into the same snow and salt, which reduced the water to that state at first, the spirit descended very swiftly, but afterwards more slowly, till it fell to the very bottom of the stem; 'twas then removed into the same glass from whence we took it, wherein were many loose pieces of ice; nevertheless it hastily ascended at the first, and was, presently after, impell'd to the former height of $5\frac{1}{2}$ divisions.

6. The condensation of liquors, by such degrees of cold as are procurable among us, is nothing near so great as might be imagin'd. On a cold day, but not frosty, having very carefully weigh'd a small round vessel of clear glass, furnish'd with a long stem, and found its balance to be one ounce, one dram, $56\frac{1}{2}$ grains, we fill'd its round part with well rectified oil of turpentine, till it ascended a little way up the stem; exactly marking its station, with a diamond on the outside of the glass: we then put them both into the scale, and found them to weigh two ounces, seven drams, $34\frac{1}{2}$ grains; when gradually pouring in $\frac{1}{4}$ dram of oil, mark'd how high it reach'd in the pipe, and so continued to add several parcels of the same fluid, always carefully weighing each quantity, and marking its height on the outside of the glass, till the liquor and glass together weigh'd three ounces, one dram, $4\frac{1}{2}$ grains. The little bolt-head was now placed with its spherical part in a wide-mouth'd glass of fair water; when, by laying snow and salt around it, we made the water begin to freeze, till a little ice was produced thereon; then carefully marking the part of the stem whereto the oil had descended, we transfer'd the bolt-head to a mixture of snow and salt, where 'twas kept for an hour or two, till we perceiv'd it fall no lower; and marking this station also, we afterwards removed the glass into a warmer air, till the oil had regain'd the highest mark from whence it began to sink. We next gently poured out of the bolt-head, into a very small glass nicely counterpois'd in very tender scales, so much of the oil till the remainder rested against that mark of the stem, whereto it fell when the water began to freeze, which amounted to $9\frac{1}{2}$ grains, tho' we might safely call them ten. After this, we poured more oil out into the same little glass, till what was left in the pipe, stood even with that mark whereto the snow and salt had sunk it; which parcel of oil happen'd to be very nearly of the same weight with the former; so that the artificial way

Experiments and Observations upon Cold.

PHYSICS.

way of freezing, employ'd in this experiment, made the oil subside as much, after it had been refrigerated and condensed by a degree of cold capable of congealing water, as that degree of cold had been able to condense it at first. And, lastly, having deducted the weight of the glass from that of the whole oil and glass together, to gain the weight of the oil alone; and having divided the weight of the whole oil, first by that of the former parcel of ten grains, and then by the weight of the second; we found that rectified oil of turpentine, of a moderate temper, exposed to a degree of cold capable of freezing common water, did, by contraction, lose a 94th part; and that being reduced to as great a coldness as snow and salt cou'd bring it, it even then lost but about a 47th part of its bulk.

7. Another attempt we made to measure the proportion, whereto water of a moderate coldness wou'd shrink by the force of snow and salt, before it began to expand by congelation: and by a trial purposely made with common water in a round glass furnish'd with a long stem, we found the water in that stem to subside so very little as to be inconsiderable; but probably a larger quantity of water and a slenderer stem, wou'd have render'd the contraction of the liquor more remarkable.

8. We also try'd to measure, by the different weight and density of the same portion of water, the change therein produced between the utmost heat of summer, the first degree of freezing cold, and the highest that art can create. And in order hereto we weigh'd, with a pair of exact scales, a glass bubble heavier than water, in that fluid, when it was of a moderate coldness, and thereby readily gain'd its proportion to an equal bulk of that water; then, by applying snow and salt, we made the water begin to freeze, and again weigh'd the bubble therein, to find what proportion an equal bulk of the cooled liquor wou'd bear to the glass; and by comparing these two proportions together, we made an estimate of the water's increased gravity and density by the action of a freezing degree of cold. In the following summer, we design'd to have weigh'd the bubble in the same parcel of water, that, by the difference of its weight therein, when render'd lighter by the heat of the air, we might obtain the information we desired. This experiment I, also, recommended to be made in *Italy*, during the summers heat; snow being there easily procurable at that time; but having hitherto receiv'd no advice of its being perform'd, nor been able to perfect our own experiment, I content myself with shewing the steps we design'd to pursue therein.

9. Whether the making of such experiments as these, with the waters of particular rivers or seas, may afford any useful instruction, as to the greater burthen a ship will carry thereon, in winter than in the summer, is an inquiry which I shall not here insist on: we may, however, observe, that the difference betwixt water cold in the extreme degree,

degree, and that of the usual standard, is not so great as some have imagin'd; for having, on a day, wherein fell snow intermixed with rain, weigh'd, in common water, a glass bubble, whose weight in air was 150 grains; but in water only $28\frac{1}{8}$ grains, and then by snow and salt made that water begin to freeze in an open glass, we found the bubble weigh'd therein not above $\frac{1}{8}$ grain less than before; so that if we may judge of the condensation of water by the increase of its weight, this shrunk only about a two hundred and thirtieth part of its former bulk.

PHYSICS.

VIII.

We come now to consider in what line of direction the refrigerating power of cold bodies acts with the greatest force, or to the greatest distance. That heat diffuses itself principally upwards, is a known doctrine, and usually holds true; whence it might be suspected, that cold had its tendency chiefly downwards. With relation to this point, we made the two following experiments.

Experiments relating to the tendency or direction of cold.

1. A very thin bubble, made flat at the bottom, that it might be the more exposed to the cold, being filled with water, and suspended by a string, at the distance of an inch, above a mixture of beaten ice and salt, wherewith we had half fill'd a large wide-mouth'd glass, the water shew'd no signs of being froze. And to this experiment agrees an observation we made, that a mixture of ice and salt did not congeal the vapour of the air, at the distance of more than half a barley corn's breadth, above the height whereto the mixture reach'd in the glass.

2. We put a mixture of snow and salt into a vial with a long neck, the round part whereof was by a weight kept under water, from whence being soon taken, the outside of the glass, below the surface of the water, was found cas'd with solid ice, and particularly about the bottom of the vial, to a vast thickness and hardness.

3. From hence, however, I will not positively conclude, that the tendency of cold produced by bodies able to freeze others, is greater downwards than upwards; for I suspect it requires more accurate experiments to determine that matter. How it happen'd I know not, that ice in the last experiment shou'd be much thicker there than elsewhere; for in other trials of the like kind, we generally observ'd the outsides of the glasses to be cas'd with ice, or cover'd with hoar-frost on that part directly opposite to the snow and salt, which mutually dissolving each other in part, and falling in a fluid form to the bottom, the undissolved part of the ingredients wou'd float upon this liquor, opposite whereto the external ice generated thereby, appear'd; so that as the mixture grew gradually thinner, the belt of ice on the outside became narrower, till at length, when the snow was quite dissolved, the ice presently vanish'd. And as in such vials the ice appear'd

PHYSICS.

pear'd not, as we said, more than the breadth of half a barley corn above the mixture, so neither do I remember to have seen it much farther below it; from whence it may, with some probability, be supposed, that the coldest bodies diffuse not their freezing power to any considerable distance, either upwards or downwards.

4. But the present experiment having been made under water, and the others in the open air, I dare not, without farther trial, determine how much this difference of the medium may alter the case in the diffusion of cold; especially since we shall presently see, that frozen eggs, suspended under water, were every where equally surrounded with a coat of ice.

5. A principal obstacle to the progress of the history of cold seems to have been, that the common method of freezing by snow and salt, is apt, like the ordinary frost, to break the glass vessels employ'd; for in both cases the fluid beginning to freeze at the top; and the property of glaciation being to distend the liquors it affects; when the upper crust of ice is grown thick, and bears hard with its edges against the sides of the vessel, it makes a greater resistance to the farther expansion of the fluid, as that is successively frozen; whence the containing glass is easily burst.

6. For this reason, I contrived to freeze the water from the bottom upwards, by mixing the salt with that part only, of the snow which was to lie under, and about the lower part of the glass placed in it. By this means the snow, contiguous to the sides, did no more than cool the water and dispose it to freeze, whilst that whereon the glass rested, being mix'd with salt, converted the adjacent liquor into ice, and so raised the incumbent fluid; which I cou'd also freeze without danger of breaking the glass, by barely applying the mixture to its sides, so as not to let it reach too near the surface of the liquor, whose upper parts were thus kept fluid to the last, and, therefore, capable of being impell'd, gradually upwards, by the expansive force of the lower.

7. No nicety of proportion need be observed in the quantities of the salt and snow made use of; neither is it requisite they shou'd be intimately mixed: a third or fourth part of the former, to one of the latter, succeeds well. I seldom add salt to all the snow, at once, unless I desire an immediate congelation; and by the method above-mention'd, I procure ice on what external part of the glass I please. And let it be observ'd, that beaten ice will freeze in this case as well, if not better than snow; for which reason, I promiscuously use either of them with salt, for the ingredients of our freezing mixture.

*Experiments
and observa-
tions, with re-
gard to the
preservation
and destruction
of bodies by
cold.*

'Tis a tradition, that frozen eggs or apples are spoiled by being thaw'd near the fire, but if immerf'd in cold water recover their natural ftate. Upon more reafons than one, we thought fit to try the experiment; but the event did not answer our expectation: however, after feveral attempts, we at length brought it to fucceed.

1. An egg that weigh'd twelve drams and one grain, being wrapt up in wax'd paper, and frozen with fnow and falt, loft four grains; 'twas then put into a difh of fair water, where it gain'd fuch a coat of ice, as caufed the whole to weigh fifteen drams, nine grains; then the ice being taken off, and the fhell very well dried, the egg weigh'd twelve drams, twelve grains. At length we broke it, and found it almoft entirely thaw'd. When froze, it floated in water, but funk when thaw'd.

2. We placed two eggs, ftroingly frozen, in a room where there was a large fire, one of them plunged in a deep wooden difh full of very cold water, and the other upon a table near it, about two yards from the fire; when, perceiving that in the water to be crufted over with ice, we took it out, freed it therefrom, broke it, and found many little parcels of ice remaining upon fome part of the white; while the other part of the fame, and the whole yolk, appear'd nearly of the fame confiftence, as if they had never been frozen; but the egg that lay dry, had both its white and yolk entirely frozen; the latter whereof, being as hard as if it had been over-boil'd, fhew'd us, when cut thro' the middle, feveral concentrical circles of different colours, with a fpeck much whiter than any of them, in its center; which laft circumftance was perhaps accidental. By the way, we only once obferved frozen eggs to fwim; and that when fuch eggs were broken, the white floated, and the yolk funk.

3. Upon repeating the fame experiment, we were convinced, that frozen eggs will thaw much fooner, *ceteris paribus*, when immerf'd in water, than when furrounded only with air.

4. Sufpending a frozen egg under water, at a diftance from the fides of the containing vefTel, its icy coat over-fpread the thread whereby 'twas hung; and we found that coat of an uniform thicknefs, tho' a confiderable quantity of ice was generated at a fmall diftance herefrom; which feem'd to owe its origin to the fame caufe; yet we cou'd not find that it any where adher'd to that which immediately cover'd the egg: 'tis poffible, however, its rudiments were parted from the egg, by fome motion communicated to the table whereon the experiment was made.

5. Having expofed fome pippins, all night, to freeze, and put them on the following morning, into a bafon of very cold water, that flood

PHYSICS.

in a warm room, they were soon surrounded with cases of ice to a considerable thickness; and here we observed, that the immersed part of a floating apple was thicker coated with ice than what remain'd above; that the extant part seem'd also harder than the other; that one being purposely laid on the outside of the basin, appear'd in cutting to be harder and more frozen than those which had been plunged under water; the latter proving almost as soft as pippins that had never been froze, but particularly in their external parts; lastly, that neither these, nor frozen eggs, notwithstanding their great congealing force, upon the contiguous water, appear'd to detain or freeze the vapour of the air, as ice and snow mix'd with salt, and included in glasses, very remarkably do.

6. After freezing some eggs in ice and salt, till their shells crack'd, we plunged one into milk, two into a glass of beer, and two more into a glass of sack; but none of them produced a grain of ice. Some others being immersed in vinegar, the saline part of the liquor began to dissolve their shells, whilst the cold of the ice therein was unable to freeze any part of the fluid.

7. I also design'd to try whether pieces of iron of different shapes and magnitudes, exposed for several nights to the freezing air, and afterwards immers'd in water, wou'd produce any ice; for the frost seems to affect such bodies. And I have been assured, that a large cheese being buried in water, in a cold country, was immediately cover'd over with ice. But for want of a frost sufficiently durable, I cou'd not obtain my desire. However, I kept large lumps of iron and other metals, pieces of glass, and some stones of a proper size, for a considerable time, longer in snow and salt, than wou'd have suffic'd to cause eggs, apples, &c. to produce plenty of ice upon being thaw'd in water; yet we found nothing of this kind upon any of the several mineral bodies mention'd, tho' kept long cover'd in cold water.

8. Ice and the juice of pippins well shook together in a single vial, produced abundance of dew, but no ice.

9. Ice and the white of an egg gently beat into a liquor, did the like; but these trials ought to be repeated.

10. That frozen apples are better preserved by being thaw'd in water, than before the fire, we are convinced by several trials; and cou'd not but wonder to see how great a putrefaction was caused in these bodies by thawing them suddenly; but in eggs the experiment is not so easily or expeditiously made.

11. This observation seems to hold equally in the bodies of men, when froze. 'Tis commonly found in the cold northern climates, that if any persons, whose limbs are froze, approach the fire too hastily, they thereby endanger the loss of them. "Upon many of us," says "Capt. James," the cold had raised blisters as big as wallnuts; which we attributed to our coming too hastily to the fire." And, therefore,

fore, the proper method is, to wash the frozen part in very cold water, or rub it well with snow, before the persons thus affected enter a hot room. I wou'd willingly have tried the effects of different kinds of thawing upon frozen beef; but failed of an opportunity. An intelligent person who had lived in *Muscovy* told me, that having two very large cheeses frozen in that country, he thaw'd one of them in water, and the other in a stove; whereby the former became much the better of the two: he added, that the cheese thaw'd in water, presently acquired a crust of ice therein.

12. *Hildanus*, in his treatise of gangrenes, tells us, "that a nobleman, who had travell'd in the more northern regions, assured him, he there once found a man upon the road stiff, and almost froze to death; whom, having carried him to an inn, the master thereof presently plunged him into cold water, whereby his whole body was covered over with ice; then having drank a glass of spiced hydromel, he was put to bed, where he sweat and recovered; but lost the first joints of his fingers and toes.

13. The experiments lately delivered, wherein ice was speedily produced on the outside of frozen eggs and apples, by immersing them in cold water, seem very well fitted to discover the causes of congelation; but I shall not here build any hypothesis upon them.

14. Whether bodies be froze by the admission of frigorific atoms, that disorder the texture of the frozen body, or the absence of some matter that, before congelation, more strongly agitated their parts, or in what other manner soever; 'tis manifest that the nature of the congealed substance is greatly alter'd from what it was before. 'Tis, therefore, proper to enquire how cold affects bodies, with regard to their preservation and the destruction of their textures. But the nature of particular bodies, the different degrees of cold whereto they are exposed, and the different times wherein the condition of each is examined, must here be carefully regarded: for we find that a moderate degree of this quality, preserves many substances; and that glaciation destroys or prejudices several others: tho' while the frost continues in them, it, almost universally, prevents putrefaction.

15. That a moderate degree of cold, conduces to preserve the greatest part of inanimate bodies, is generally acknowledged; nor, perhaps, does any degree of this quality below freezing, spoil what is exposed thereto. "At *Modena*," says *Bartholin*, "they lay up snow in their repositories, where I have seen them, during the heat of summer, long preserve the flesh of animals from corruption." And Captain *James* relates, that "on the 9th of *May*, he drew up from under water, five barrels of beef and pork, four butts of beer, and one of cyder, where, tho' they had lain all the winter, he found them never the worse for it." He mentions it also, as a remarkable thing, "that a cable,

"which

PHYSICS.

“ which had lain buried in ice, during the whole winter, was found upon being thaw’d in June.”

16. *Bartholine*, also, relates from *Sminlerus*, that “ a large quantity of snow, falling from a part of the *Alps*; buried above sixty *Switz* soldiers of the company that happened to be there, marching over them. In which cases, the bodies lie till the beginning of the summer, when the snow, being somewhat dissolved, they are found fresh and uncorrupted. And of this,” adds he, “ I my self am an eye witness.”

17. Many instances might be produced to shew that most inanimate bodies, while actually froze, will discover no putrefaction; and the thing it self seems reasonable: because, whether the fluid parts are here wedged in by the intruding swarms of frigorific atoms, or whether those restless particles that keep a body soft or fluid, are called forth by the causes of glaciation; there must be an unusual rest in the moveable parts of such substances, as are either the cause or necessary attendants of corruption.

18. An ingenious man, who had made some stay upon the coasts of *Sweden* and *Denmark*, told me, that dead bodies would, there, of themselves, keep untainted during the frosty season; that is, for three or four months together. *Bartholine* informs us, that the bodies of men, kill’d during the hard weather, remain stiff in the posture wherein they expired. “ After a great slaughter of the enemy,” says he, “ in the battle fought near our city, Feb. 11. 1659. the field was found strew’d with stiff carcasses, some whereof shew’d anger in their faces, some had their eyes lifted upwards, and others seemed threatening a blow with their sword; and all lay in different postures. And when, in the following spring, it began to thaw, an entire man rose up from the bottom of the sea, (that had been frozen) sitting on his horse, and holding something in his hand.” “ Near six months,” says Captain *James*, “ after our gunner was dead, and committed to the deep, at a considerable distance from the place we were now in, May 18. our master espied his corps in the ice under the gun-room ports; whence having dug him, we found his scent no more disagreeable, than when first thrown over board; but his flesh would slip up and down his bones, like a glove on a man’s hand.”

19. Some *English* relate, as we find in *Purchas*, of the *Samejeds*, that they buried their dead on the sides of the hills, and raised a pile of stones, so loosely over them, that the bodies appear thro; but the air is so piercing, that it keeps them from putrefaction.” The same author says, in the description of *Isleland*, “ that the method of managing fish there, is, having first taken out their bones and bowels, to throw them on heaps in the open air; the purity whereof is such, that they are thus hardened and preserved better than by salt.” The physician to the emperor of *Russia*, told me, that dead bodies, if thoroughly frozen, wou’d with them continue uncorrupted

uncorrupted till the thaw; tho' it happened not for four or five months after the death of the person: he added, that he had received the venison of elks, at *Moscow*, untainted, tho' it came without salt, some hundred of leagues; and that all flesh, when well frozen, would remain sweet for a very long time; that, when kept congealed too long, it grew dry and insipid, and would not afford so good broth as meat that had never been frozen; and that if leisurely thaw'd, it receives far less damage, and will roast well; but if laid to the fire before 'twas uncongealed, it wou'd neither roast nor eat tolerably, but continue raw in the middle, tho' kept there turning ever so long upon the spit.

'Tis farther remarkable, what the merchants of *Copenhagen*, who trade to *Spitzberg*, in *Greenland*, relate, "that the extreme cold of those parts, will suffer nothing to putrefy or corrupt; so that corps there, continue sound and entire for thirty years after burial."

20. Whilst bodies remain frozen, the cold, probably, by preventing that irregular motion and avolation of their particles, whence corruption proceeds, may keep its pernicious effects from appearing; but when once that impediment is removed, many substances immediately discover a discomposure of their texture thereby occasion'd. This, in some cases, will be manifest to the sight: thus by freezing an ox's eye, the crystalline humour loses all its transparency, and appears perfectly white throughout. The person, also, who made the experiment with the two frozen cheeses, observed both of them to be manifestly impaired by the cold; tho' one much less than the other.

21. "The *Dutch* sailors likewise," says *Gerat de Veer*, "when they winter'd in *Nova Zembla*, had their strong beer so frozen, that they were obliged to melt it for use; the spirituous part whereof being fluid, like yeast, and too fiery to be drank alone, they mixed it with the dissolved ice, which neither then, nor before, had any strength or taste." And Captain *James* relates, that "having in his cold station, reserv'd some *Alicant* wine, till the spring; when, mixing it with water, it made but a very weak liquor; having lost its virtue, by being frozen."

The *Russian* emperor's physician inform'd me, that when some very strong *French* claret, that was frozen, came to be thaw'd, he found its colour tolerable, and the liquor very little impaired; that a weaker sort, by this means, lost its colour, and became much worse; but that the third part of them remained uncongealed: whence the cold, whereto they were expos'd, appears to have been nothing near so violent as that experienced by the *Hollanders* and Captain *James*. The same physician, likewise, told me, that having a quantity of strong beer, in great part frozen, he found the ice to retain some taste of the hops, tho' it seem'd dispirited, like phlegm.

PHYSICS. 22. A man of learning, told me, that in a *Northern* country, less cold than *Muscovy*, he observed some beef, which, having been very long frozen, was almost insipid when it afterwards came to be eaten; and that the broth it afforded was little better than common water.

23. I designed, but wanted opportunity, to try whether some particular plants and parts of the *Materia Medica*, with whose specific virtues I was acquainted, would lose their respective qualities by a thorough congelation, and different methods of thawing; as whether, for instance, thaw'd harts-horn, the quantity and strength of whose salt and saline spirit should, before its freezing, be tried by distillation, wou'd, after having been long congealed, yield, by the same treatment, a like proportion of those substances. We had, also, thoughts of making experiments with amber and load-stones, to see whether the most intense degree of cold, long continued, would affect the attractive faculty of the former, and the attractive and directive virtue of the latter.

24. Credible testimonies are not wanting to shew, that intense cold may have very considerable effects upon the texture, even of solid and durable bodies. 'Tis commonly allowed, that mens bones are more apt to break, by falls, in frosty weather, than at other times; and 'tis usually found that the steel laths of cross-bows, are render'd so brittle by cold, that more than ordinary care is required to prevent their snapping in the winter: and I am, also, inform'd, by an ingenious overseer of buildings, that those who deal in timber, find it cleaves more easily in hard, than in open weather. But these effects of cold, are trifling to what may be met with in more intemperate regions.

25. Captain *James* says of the timber he used in *Charlton-Island*, "that every piece was thaw'd in the fire, before the carpenter cou'd work it; and that they were obliged to thaw the standing trees, in the same manner, before they could fell them."

26. Two different persons also assured me, that in extreme frosty weather, they had observed the timber of the wooden houses in *Muscovy*, to crack with a loud and surprizing noise, but especially in the night.

The above-mentioned physician told me, that the stones used for building in *Russia*, were frequently reduced to dust by the cold; and that he had often, in sharp frosts, especially if unattended with snow, heard, during the night, the trees cleave and crack with a frightful noise; that the out-side of the fir-trees, used in their buildings, sometimes did the like; and that both of them would thence receive large gaping clefts, which continued till the thaw; when they would close up again of themselves.

27. And a physician, who lived for some years in one of the coldest plantations of the *West-Indies*, assured me, he had found the bricks he employ'd in building, very apt to spoil by the long and vehement frosts

frosts of the winter there; and 'twas usual, he said, for the brick-houses of these parts to decay much sooner than ours; which he attributed to the excessive cold of the climate, that crumbles the bricks, and moulders them away. This may seem the more credible, supposing no defect in the bricks, if what a learned and credible author relates be true, as to the power which freezing cold had to break even solid marble. Nay, *Olaus Wormius* declares, that even brass instruments have been broken by the cold. And to this we may add, that the *Dutch*, in their stay at *Nova Zembla*, found some of their beer-barrels, with the iron hoops of others, frozen to pieces: tho' this effect was not, perhaps, immediately owing to the frost, but the expansion of the liquor in the vessels.

28. General *Drummond* assures me, he has seen ponds frozen strong enough to allow cannon to pass over the ice thereof, while they yet contain'd plenty of live fish, which, if caught and packed up immediately, wou'd, of themselves, continue sweet for about a month. 'Twas remarkable here, that the fish, being drawn out of the water, and exposed to the cold air, were immediately frozen as stiff as a board; when, said he, if they had been thaw'd by a fire, that would have quite spoiled them: and flesh, by the like treatment, becomes incredibly hard and tough; but both being kept in cold water, they will there thaw, become tender, and fit for dressing; tho' in thawing them, the General had not observed them to acquire a coat of ice. The same person farther told me, he had frequently seen men with their noses and upper part of their cheeks frozen, while they themselves were not aware of it: the remedy for this, he said, was to rub the frozen parts with snow; a warm room, being carefully avoided before its application. In *Lapland*, it seems, they have another present remedy to restore frozen limbs, by anointing them with the fat of toasted cheese made of deers milk. But the other is the general practice in *Russia*, as I am inform'd by the physician to the Emperor of that country; and the Doctor told me he had discoursed with a man, who in his youth was frozen all over, by quitting his sled, and using exercise till he almost sweat; and then returning to the sled again: and thus he might easily have died, had not the company accidentally observed his condition (for the person who is froze, seldom finds it himself) and rubbed him over with snow. He told the Doctor, that during the whole time of his being thus affected, he felt no pain; but as he recovered, perceived such a kind of pricking as happens in a part benumbed by leaning upon it.

29. 'Tis the custom in *Russia*, to thaw their frozen fish before they dress it, by letting it lie in cold water, till cover'd with ice, which having taken off, they lay it in other water, and again take off the ice; and this they repeat, till no more ice appears.

30. A physician of my acquaintance, having purchased some *Malaga* sack at *Moscow*, which was drawn from a frozen hog'shead of the same liquor, it proved much better and stronger than was expected; but the remaining part of the ice being thaw'd, was little more than phlegm.

PHYSICS. The Doctor, also, observed, the like to happen in some other liquors: he did not, however, find that the spirituous part always retired to the center of the vessel, but that it lay sometimes interspersed among the ice.

31. Some sailors having left a barrel of strong beer on shore in *Greenland*, found it at their return thither, the year following, very hard frozen; but running a heated spit into the middle of the ice, there issued out a turbid liquor, that was exceeding strong and spirituous, whilst the frozen part was almost insipid.

32. General *Drummod* acquaints me, that the *French*, and sometimes also the *Spanish* wines, yearly brought from *Archangel* to *Moscow*, are so frozen at their arrival thither, that the owners are obliged to flave the casks, cleave the ice with hatchets, and send it away in jars; and when this is design'd to be reduced to liquor again, they place it in another cask, and bury it deep in ice or snow, where it gradually thaws, without receiving much damage.

X.

Experiments
relating to
the expansion
of water, and
aqueous fluids
in freezing.

1. That water and other fluids are condensed by cold, in proportion to the degree wherein that quality affects them, has been generally allow'd; till some speculative men of late, question'd the truth hereof, upon account of the levity of ice, and maintained that body to be not condensed, but rarified water.

2. And, indeed, if in our method of freezing water, from the bottom upwards, a bolt-head, fill'd till the fluid reaches into its stem, be employ'd, the ice will ascend much higher than the water did before it was froze; and upon the gentle thaw of that ice, the fluid it turns to, will descend to the height it stood at, before its congelation began.

3. There are other ways to manifest the expansion of water by freezing. Having poured a proper quantity of water into a strong cylindrical earthen vessel, we expos'd it, uncovered, both to the open air in frosty nights, and the operation of snow and salt; and observed that the ice produced in both cases reached higher than the water before 'twas froze. And if a concave cylinder, made of any compact matter, be slightly stop'd at one end with wax, and filled with water at the other, and then that, also, be closed in the same manner; if, I say, this pipe be suspended in air sufficiently cold, the contain'd water will be froze, and the stopples at both ends, or at least at one, will be thrust out; and a rod of ice appear thereat, in continuation with the tube.

4. Having caus'd some large strong bottles to be fill'd with a congealable liquor, (excepting their necks which contain'd sallet oil,) I observed that, during a very long and sharp frost, the contain'd water was so far expanded by congelation, that it not only thrust the corks, but the congealed oil, together with the frozen water, out of the necks; while

while there appeared, above the upper part of the bottles, cylinders, several inches in height, consisting partly of concreted oil, and partly of congealed water, with the corks on their tops.

5. But 'tis said, in defence of the vulgar doctrine, that the cold of the external air, contracts what is contain'd in the glasses, when they break in frosty weather, and bursts the sides thereof, to fill the space deserted by the shrinking of the internal fluid; for fear a vacuum should be left in the glass. The preceeding experiments, however, may serve to shew the contrary: and tho' vessels only half filled with water, are often burst by this means; we have sufficiently accounted for that phenomenon, without the help of a *Fuga vacui*, or the weight of the external air, by the bare expansion of the contain'd liquor; the glaciation whereof begins, as we have formerly said, at the top; where the ice first strongly presses against the sides of the glass: whence the water is pressed between that and the bottom; and consequently by its expansive force in freezing, bursts the including vessel, if it make not a proportionable resistance. But farther, if water be frozen in a broad vessel, that is too strong to yield to the force of the frost, the surface of the ice contiguous to the air, will rise convex; the expansive power of the fluid prevailing there more than against the sides or bottom of the vessel. And, lastly, having carefully sealed three very light and thin glass bubbles, of different shapes and sizes, whilst the air, within them, was of a convenient temper, we exposed them sometimes to very frosty weather, and at others, to a mixture of snow and ice, but could not perceive, that any of them were so much as crack'd thereby; so that if the included air was here, according to the popular notion condensed, the space it deserted was a vacuum; whence consequently the bubbles would have been broke.

6. Having filled several long vials to the lower part of their necks with common water, and left them all unstopp'd; not only one of them that I stir'd up and down in a mixture of ice, salt, and water, was suddenly broken upon the congelation of the contained water; but many others that were exposed to freeze more leisurely in the air, were likewise broken to pieces by the expansion of the freezing water; as appeared both by the gaping cracks, and because the ice was considerably risen in the necks, above the former stations of the water: and if it had been more easy for the included water to gain room, either by stretching the glass, or leaving the superficial ice congealed, at first, in the neck, or by both these means together, than to break the vial, it would, probably, have remain'd entire.

7. Not only water, but other moist bodies expand by cold. When upon exposing eggs to a sufficient degree of this quality, the contained moisture was turned to ice, it burst the shells asunder, and occasioned many gaping cracks therein.

8. Milk, urine, and *Rhenish* wine, being severally exposed in glass-eggs, to freeze, they were not observed to subside before they rose;

PHYSICS. the urine began to swell much later than the other two, tho', at length, it ascended much higher than they; the wine rose an inch above its mark, milk two, and the urine six or seven.

9. We poured a strong solution of *Dantzick* vitriol, into a cylindrical tube, sealed at one end, till it rose to the height of six or eight inches therein; then freezing it with snow and salt, the liquor became very opaque, and appeared as if it had been wholly turned into vitriol, except a little that remained at the bottom, transparent and fluid; while the ice here rose considerably higher than the solution did before congelation. 'Twere worth trying, whether even firm, solid bodies, would not dilate with a somewhat excessive cold. The invisible moisture in the air, before rainy weather happens, apparently alters the dimensions of doors, window-shuts; and such wooden work as has not been well seasoned. Much more water is used to make bread than what exhales in the oven, yet the remaining water is invisible; and thus, hart's-horn, sponge, and many other dry bodies, afford, by distillation, plenty of phlegm, which cannot be wholly attributed to the operation of the fire upon them. Such considerations make it probable, that the moisture actually existing in solid bodies, may dispose them to swell in freezing. This experiment, carefully made, might give light to the strange phenomenon, observed by the *Dutch* in *Nova Zembla*, where their clock, says *Gerat de Veer*, was so frozen by the cold, that an additional weight would not make it go. And the same thing is related by Captain *James*, to have happened both to his clock and watch; tho' they were constantly wrapped up, in a chest that stood by the fire side. This effect, indeed, might possibly proceed from other causes; but if, as we formerly observed, the frost can get into metals, it may also distend them; from whence, in this case, that correspondence between the parts of the clock, that is necessary to its motion, may be destroy'd: thus I have seen the exact parts of an iron instrument, would by no means fall in with each other, when expanded by heat.

10. Having almost filled a bolt-head, whose stem was purposely drawn very slender, with water, and placed it in a mixture of salt and ice, the water immediately appeared to be a very little depress'd; tho' it afterwards fell no lower, nor exhibited any other phenomena of freezing water, except that when the fluid began to congeal at the bottom, it had a manifestly quick ascent. We, therefore, caused the bolt-head to be made with its spherical cavity $3\frac{1}{2}$ inches in diameter, and stem no thicker than a raven's quill; and filling this to a proper height with water, we observed, upon immersing the glass in the same kind of mixture, that the water instantly ascended the length of a barely-corn in the stem, with the utmost velocity; after which, the water slowly subsided again to its former station: which agrees very well with the supposition of the *Florentine* virtuosi, who imagine so sudden a change must proceed from the contraction of the containing glass.

glass. But, upon repeating this experiment several times, we could not find, what they observed at *Florence*, that the water was considerably depress'd soon after its first subsiding, before it began to rise; tho' I have formerly found water to suffer some degree of condensation by the action of a frigorific mixture, before it began to yield any ice. We, farther observed in this experiment, that after the sinking, or immediately upon the first rise of the water, the surface rested a while in the same place, till the upper part of the water began to ascend by reason of the glaciation of the lower; but this pause was very uncertain in its duration, according to the different strength of the action of the mixture on the adjacent water. The fluid beginning to freeze here, rose with a surprizing velocity up the stem; so that in the space of a minute, it would often shoot to the height of several inches; and would, probably, have risen much higher, if the stem had been of a sufficient length. In all the repetitions of this experiment, I never saw any considerable intumescence of the water immediately precede glaciation; but the ascent of the fluid was always attended with, if not preceded by the actual freezing of some parts of the water that lay nearest the mixture: which I take to be the cause of this phenomenon. But so small a degree of glaciation is required to make the fluid sensibly rise, that it requires attentive eyes to discover it. Lastly, we remarked with pleasure, that if the glass in this experiment, were immediately taken out of the mixture, after the water began to ascend; the very thin film of ice would be suddenly thaw'd hereby, and the liquor begin again to subside in less than half a minute; but upon replacing it in the ice and salt, immediately after the dissolution of the films of ice, the liquor began again to freeze in an instant: so that ice has shot up into the stem, in the space of half a minute from its return; and within a minute and a half more the cavity of the spherical part has appear'd filled therewith.

XI.

1. It must not be universally concluded from the preceding experiments, that all liquors will expand by any degree of cold whatever; for in our trials with spirit of wine, *Aqua fortis*, oil of turpentine, and other liquors, that we could not bring to freeze, the contrary appear'd; as also in oil congealed by cold: so that a great difference ought to be allowed between water and aqueous liquors on one side, and oil, and several other oleaginous, highly spirituous, or corrosive fluids on the other, as to the change of their dimensions by cold. We have not, however, made a sufficient number of experiments to reduce this matter to a certainty; but this, in the general, may be said, we remember no sensible expansion produced in any liquor, by cold, but rather a manifest condensation, unless it were actually froze.

Experiments relating to the contraction of liquors by cold.

2. Upon surrounding spirit of wine, contained in a small glass egg, furnished with a very slender stem, with a mixture of ice and salt, for several

PHYSICS.

several hours; it froze not at all, but gradually subsided, the length of $\frac{1}{4}$ inch in the stem; and tho' it afterwards seemed to rise a little, yet it never, during that time, ascended to its first station.

3. Pouring mercury into a bolt-head, till it reached pretty far into the neck, which was purposely made more slender than ordinary, purging it of the air it contained, and placing it in a mixture of ice and salt; the cold affected it so much, that we discerned it to move downwards the length of two inches in the neck: which great descent cannot possibly be attributed to the contraction of any remaining air; tho' it had thereby been reduced to a point. We found, also, that the mercury, tho' not frozen by this means, retained part of its acquired cold, for many hours after; for it continued below its original standard, tho' kept all night in a warm room.

4. We poured common oil into a small glass-egg, with a slender stem, till it rose considerably above the oval part of the glass; then placing a mark at the station of the fluid, we set the vessel in snow and salt; whereby it subsided, till it became quite congealed; when it appeared shrunk above an inch below the mark, whereto, upon being thaw'd, it re-ascended.

5. This experiment was repeated with nearly the same success; but we now found, that if the glass were removed from the mixture to any place near the fire, the oil not only thaw'd, but ascended above the mark. For a third experiment, we sealed up the oil in the same glass, which gave us still the same phenomenon. That the congealed oil was here really condensed, appeared from its sinking in the same kind of oil cold and unfrozen; notwithstanding the several bubbles of air that usually adhered to each lump, wherewith we made the experiment. This was not only tried with oil, congealed by snow and salt, but with some less frozen by the bare cold of the open air; but the latter appeared to sink more slowly than the former; and lumps of it would not continue under sack, or claret, but if thrust down herein, presently emerged.

6. Whether chymical oils, tho' they also shrink with a moderate degree of cold, will contract or expand by freezing, we cannot determine; the highest degree of cold we could procure, proving insufficient to congeal them: but surrounding a short glass pipe full of liquid oil of aniseeds, with ice, obtained in a warm season, we observed, when it had hereby lost its fluidity, 'twas considerably sunk below its former height.

7. We also made the experiment with the empyreumatical oil of guaiacum, by exposing it, in vessels of a proper shape, to the greatest degree of cold we could produce; but it did not thereby lose its fluidity, only shrunk very manifestly.

8. We immersed two sealed weather-glasses, (filled the one with spirit of wine tinged with cochineal, the other with a blue mixture of the spirit of human blood, copper, and spirit of wine) in water, till it began to freeze; when removing the glasses into oil of turpentine, surrounded with

with snow and salt, the liquors of both thermometers considerably subsided, and the blue one above half an inch; whence, by the way, it farther appears, that the air can impart a greater degree of cold than is required to freeze water, or than ice itself will always communicate.

9. Essential oil of aniseed being poured into a round glass fitted with a stem, till it rested at the height of five inches above the ball, we placed the glass in a vessel of water made cold by sal-armoniac; whereby, when the oil was coagulated, almost like of *Sperma Ceti*, its upper surface, we found, had shrunk three inches below the mark it first stood at: and the oil, when thus congealed, notwithstanding the many bubbles of air it then contain'd, wou'd sink in water, tho' when liquid it floated thereon.

XII.

1. What gave the moderns their first hint, to suspect water to be expanded by freezing, was the floating of ice upon water; which is most visible in large quantities of that concrete: for in small fragments it will sometimes rise but very little above the surface of the fluid; tho' sailors complain, that, in the frozen seas, they often meet with floating rocks of ice, as high as the masts of their ships. Now, in case the ice be solid, and not composed of several fragments cemented together, so as to leave large cavities fill'd with air, 'twou'd be easy to determine *a priori* its height above the water; supposing circumstances as they stand with us: for a prism of ice floating, erect, in fresh water, wou'd, according to our experiments of the expansion of water by freezing, have its immersed part eight or nine times longer than its extant.

*Experiments in
confort, relat-
ing to bubbles,
the supposed
cause of levity
in ice.*

2. Pieces of clear ice, apparently free from bubbles, wou'd not, in our trials, sink in spirit of wine, of the first distillation from brandy, and floated in that drawn from quick-lime; but if the spirit were well warmed, 'twou'd sink; and sometimes slowly emerge, or remain suspended, as the liquor grew cold again; whilst the ice, thaw'd by the heat, stream'd visibly thro' the lighter spirit: common water, however, tho' heated very hot, sustain'd the fragments of ice put into it, which in oil of turpentine, or thrice rectified spirit of wine, sunk like a stone.

3. That the levity of ice, compared with water, proceeds from the bubbles of included air, which cause it to possess more space when congealed, than when fluid, is evident from its texture. But if this alone be the cause hereof, many minute bubbles, invisible to the naked eye, must be contain'd in ice; for, altho' numerous bubbles are conspicuous in some parcels hereof, and even render them whitish and untransparent; yet others that were clear as crystal, have been observed to float on water. We, therefore, examin'd some of the latter sort.

PHYSICS.

sort with an excellent microscope; but cou'd not by this means discover a sufficient number of bubbles to persuade us, that these alone were the adequate cause of the levity of ice. One piece, in particular, appear'd quite destitute of bubbles, when view'd with this glass; yet, when plunged under water, it wou'd presently emerge; while another, less clear, shew'd plenty of bubbles, some whereof were small as pins heads, and others so exceeding minute, as to be almost invisible, thro' the microscope itself. It may be here remark'd, what will presently be proved, that the absolute weight of ice, and the water that afforded it, are the same. Bubbles, however, must, doubtless, be part, if not the whole of the cause, of the levity and expansion of ice; and therefore, their generation is one of the most considerable phenomena of cold: and to find out how those cavities are produced, and if perfectly full, what substance they contain, is no trifling enquiry into the nature of this quality.

4. Mr. *Hobbs*, with some others, seems to think the expansion of water by congelation, is caused by a fresh insinuation of the external air, which constitutes the bubbles observed in ice. But then, how happens it, that when oil is frozen, the admission of the air does not expand, but condense it? However, pouring water into a glass-egg, blown with a long stem, till 'twas almost fill'd thereby, we sealed it hermetically to prevent any insinuation of the air; when, exposing it to congelation, the frozen water manifestly expanded, and swelled with numerous bubbles, which often gave it a whitish opacity. And, metalline vessels, also, being fill'd with water, and carefully stop'd, did not prevent congelation, but the cold expanded the liquor, and turn'd it to ice, with plenty of bubbles.

5. 'Tis very improbable, that bubbles shou'd be produced by the air contain'd in the glass, mixing with the water that was hermetically sealed up, because, if bubbles must cause the expansion, how shall the water be at first expanded to reduce the air into bubbles? Besides, 'tis certain, the air retains its station above the water, and keeps together in one parcel; as we shall see hereafter. Moreover, ice and bubbles here usually begin to appear from the bottom of the vessel; in which case the air, a body so much lighter than water, cannot be supposed to force its way thro' it; especially since it does not appear to descend in bubbles, as is usual where air penetrates water. But where the vessel is quite filled before 'tis stopped, no air can dive into the contain'd water, because none is left to have that effect. And lastly, if all the bubbles were made of real air and fill'd therewith, it wou'd emerge upon thawing the ice; and a quantity thereof be obtainable, capable of filling the excess of space possessed by water, when froze, above what it took up when fluid: which is contrary to our experiments made to that purpose. Upon trial, however, we find that

that these bubbles contain but little air; not more, perhaps, than usually lurks in the particles of fluids.

6. And that all of them are not filled with the air originally contain'd in the water, appears from the expansion of the water, and the quantity of space possess'd by the bubbles; which space cannot be adequately fill'd with the latent air, unless the same parcel of matter cou'd really fill more space at one time, than at another; which seems physically impossible. But the following experiments will give more light in this matter. (1.) Having kept fair water in an exhausted receiver, till it afforded no more bubbles, we immediately removed it into snow and salt, where it continued for a considerable time, before it began to freeze, whilst we observed it not to swell near so much as common water; and the ice was but thinly stored with bubbles; tho' a few very small ones appear'd therein, upon viewing it, placed between the vigorous flame of a candle and my eye. (2.) Part of this same ice, being gently thaw'd, and poured into a glass tube to freeze afresh, it swelled considerably, and burst the glass; the ice appearing opaque with bubbles. (3.) We poured water into a small glass-egg, till it rose to the height of an inch within the stem, and then placed it in a tall cylindrical receiver; after a thorough exhaustion whereof, during which, the water seem'd to boil very considerably, and for a long while together, we removed the glass-egg into a vessel of ice and salt, and there suffer'd it to remain for twelve hours, that all the water, except what was in the neck, might be perfectly froze; at the end of which time, we found it to have risen far above its original height: removing then the glass into the open air, we quietly suffer'd the ice to thaw, whilst in the external part of the ice, near the sides of the egg, we beheld plenty of bubbles; but when this was dissolved, the rest of the ice appear'd of a peculiar and unusual texture, without any visible bubbles, but almost resembling a piece of frosted glass; the parts causing the asperity, seeming very thick set: this ice, however, floated in the liquor into which the other was melted; and whilst a lump hereof remain'd, about the bigness of a walnut, we convey'd the egg back to the receiver, which having exhausted, a few bubbles, at length, appear'd in the water; each whereof was an hundred times less than one of those, first taken notice of in the same. Some small bubbles also here appear'd in the ice, which were not perceiv'd before; but it did not dissolve manifestly faster *in vacuo*, than in the open air; but being, at length, wholly uncongealed, we took out the glass, and found the water had subsided to its original standard, if not, rather, a very little below it. The expansion of the ice was here considerable; for the water rose $3\frac{1}{2}$ inches in the stem, tho' the whole quantity employ'd, were but two ounces and a half.

7. We fill'd a small cylindrical tube, closed at one end, with water, and thrust it into a wide-mouth'd glass half fill'd with ice and

PHYSICS. salt; then conveying all into a receiver, and pumping out the air, a great number of bubbles issued both from the upper and lower parts of the water; most of which broke into the receiver. Then finding the engine to continue stanch, and by the swelling of the higher part of the water, the under to be frozen, we let in the external air, removed the receiver before the mixture was half melted, and found the water in the cylinder, as high as that mixture had reached, turn'd to ice, wherein were some large conspicuous bubbles, and small ones enow to render it opaque.

8. Upon pouring water into a glass-egg, till it rose to a certain noted height in the neck, and setting it to freeze in a mixture of ice and salt, that reach'd within an inch of its upper surface, we observed the following particulars. (1.) The water did not sensibly subside before it began to freeze. (2.) Within a quarter of an hour, it began to swell, and some of its parts that lay next the sides and bottom of the glass were frozen. (3.) In the space of an hour, from first exposing the water to freeze, it rose $4\frac{2}{9}$ inches above the mark; and before 'twas taken out, it had ascended $5\frac{1}{2}$ inches higher than the same, tho' part of the water then remain'd unfrozen. (4.) The lower parts, only, of the water were congealed, and not its upper surface. (5.) No considerable bubbles, during this great elevation, appear'd in the unfrozen parts of the water; but the ice seem'd full of them; and several, towards the latter end of the experiment, were grown very large and differently figured, whilst others shew'd less. (6.) Upon taking out the glass whilst the water was at the highest, and pouring in oil till it rose two inches above the former surface, we nimbly sealed the glass, during which operation the water subsided a little; but replacing the glass in the mixture, the water soon regain'd its former height, whilst the height of an inch and half of the sealed glass was unpossess'd by the two liquors. (7.) In these circumstances we carefully weigh'd the egg, first in air, and then in water, the better to discover if the glass shrunk; and whilst it hung balanced in the latter, the ice thaw'd, and many bubbles, great and small, ascended, the former with a wrigling motion, and vanish'd at the top. (8.) As the ice thaw'd, the water and oil descended, till the whole was dissolved; at which time we observed the scales to continue horizontal; and that the water was again subsided exactly to its original standard, notwithstanding so considerable an avolation of bubbles. (9.) Inverting the glass, we gently broke off its sealed slender end, under water, part whereof being impell'd up, sensibly reduced the air at the opposite end within narrower bounds. (10.) The glass being again inverted and held still, the water newly admitted, together with the former, and the oil, possess'd the same places with the water and oil before the glass was sealed. (11.) Lastly, upon throwing out the oil, and employing a little of the same water, occasionally, we found the glass,

glass, fill'd to its highest mark, weigh'd 4374 grains, but when fill'd to the lowest mark 4152, and when quite empty, only 1032 grains; so that the water contain'd between the highest and the lowest mark, and rais'd by glaciation, was about a fifteenth part of the whole, and wou'd probably have been more, had the whole been frozen.

9. We poured water into a large glass-egg, till it reach'd an inch high in the stem; then exposing it all night to a mixture of snow and salt, placed below the bottom of the stem, we found the water, about ten the next morning, risen fifteen inches above the former height; the whole cylinder of water continuing fluid: then suffering the water to swell freely, it reach'd, within seven or eight hours time, to the top of the glass; so that a drop or two ran over; that is, it ascended nineteen inches above the first mark; which scarce allowed us to seal up the end: but, afterwards, removing the vessel into a warm place till next morning, and all the ice in the belly being thaw'd, the water subsided a little below its first station, by reason of a little that was spilt in sealing the glass; but here an accident hinder'd us from prosecuting the experiment farther.

10. Another glass, furnish'd as the former, being placed to freeze in the same manner, its water rose near an inch in less than an hour; when that in the ball and juncture of the neck was frozen into *lamina*, which after an hour and quarter disappear'd in the neck; but in the ball there seem'd a white ice; and the water ascended in all $4\frac{1}{2}$ inches. Abundance of small bubbles now, perpetually, rose thro' the neck, and continued to do so till the thaw was finish'd; the white ice appearing full of bubbles. Upon prosecuting the experiment farther, the water continued to ascend till it had reached about eight inches above the first mark; when, drawing the top of the pipe into a very slender cylinder to be seal'd, we again placed the glass in the mixture, that the air heated by the lamp, might cool; whereupon the water swell'd till it began to run over at the orifice of the small pipe, which we then immediately sealed up; so that the whole glass appear'd full of water, except an inconsiderable quantity of rarified air contiguous to the seal'd end. The egg being now brought into a warm room, stood there all night, and part of the next morning, before the ice was quite dissolved; after which, we found the water subsided to its original station. Things standing thus, we inverted the glass, and plunged its sealed end under water, then broke it off, whereupon the external air forced so much water into the pipe, that the upper surface reach'd seven inches above the first mark, and left an inch and half of the stem unpossess'd, below where it began to grow exceeding slender, and, also, as much of that part as, by guess, amounted to a quarter of an inch; whence the bubbles that caused the water to swell, and appear'd in the ice, were equal to $1\frac{1}{4}$ inch of air, which, consequently, was, in great measure, generated by this process, as well as seven inches ei-

PHYSICS. ther of a *vacuum*, or some subtil substance, which for want of elasticity cou'd not be air.

11. Upon breaking a seal'd glass, fitted as the former, under water, a cylinder of $10\frac{1}{2}$ inches was impell'd into it, whilst the mark where- at the ice had stood, was $11\frac{1}{4}$ above the first.

12. In the bolt-head that shew'd us the greatest condensation of air, the water was by cold made to rise almost a foot above its original station; when the glass being sealed, and the ice being permitted to thaw gently, the water sunk back to the first mark; we then inverted the glass, and broke off its apex under-water, whence an addition of above eleven inches of water was, with some noise and violence, driven into the tube; so that near $\frac{7}{8}$ inch of air appeared to have been generated or separated in the operation.

13. Having caused the water to swell about ten inches in the same vessel, we ordered it as before, and found the additional quantity of water to be, also, about ten inches.

14. We observed, not only in water, but other aqueous liquors, that the ice-bubbles were not filled with air; for having froze milk and urine, and suffered them to thaw, they severally subsided near their original stations; when inverting the containing glasses, and breaking them under water, the milk and urine were manifestly impelled upwards, and the stems appeared to have acquired an addition of five or six inches of water.

15. Upon breaking, in like manner, a sealed glass of claret-wine, that we found in part frozen, the water was pressed up $\frac{1}{4}$ inch; which could not have happened if the generated bubbles had been full of genuine air. All these experiments, however, only shew us, that these bubbles are not filled by air, but leaves us in the dark as to what it is that fills them.

XIII.

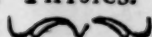
Experiments to
measure the
expansion of
liquors by cold.

1. We have employed two different methods to measure the expansion of fluids; and first, by pouring a certain number of single weighed ounces of water into a bolt-head, and marking the height whereto each of them rose, till the stem of the glass was filled, and afterwards pouring some of them back again, we suffered the remainder to freeze from the bottom upwards; and found that the ice made from eighty two parts of water possess'd the space of ninety one and an eighth; whence the water expanded by cold, took up about a ninth part more space than before congelation.

2. After the same manner, we found at another time, that fifty five parts of water stretched, by freezing into the space of $60\frac{1}{2}$; about six of the former parts remaining unfrozen: so that this experiment nearly agrees with the preceeding.

3. The

3. The other way we made use of was, to fill a cylindrical tube, sealed at one end, to a certain height with water; which we marked on the outside, then kept the glass erect, and froze the water upwards, whereby we have observed it to acquire greater dimensions, by a tenth, in the form of ice, than when fluid; tho' small varieties may often happen from the difference in the water applied in this experiment, and other circumstances; and, accordingly, I once found a greater expansion than the last mention'd.



4. Exposing water to freeze in a very even cylindrical glass, we found it expanded about an eighth, or, at least, a ninth part upon glaciation: this we observed, also, a second time, and supposed the intumescence might have still been greater, but that the freezing succeeded ill in the cylinder.

5. Sealing up a bolt-head, whose stem stood seventeen inches above the surface of the contained water, and placing it in our freezing mixture for eight or nine hours, the water ascended above $15\frac{1}{2}$ inches; when being left to it self for an hour, the sealed end of the glass was blown off, quite round, and the bottom burst into many pieces; the whole body of the pipe remaining sound.

6. We sealed up some water that had been well purged of air by the air-pump, in a bolt-head, whose pipe rose five inches above the upper surface of the fluid; then setting the glass in a frigorific mixture, it exhibited an ice very prettily figured, and without manifest bubbles; and in less than two hours time, the water was impelled up $4\frac{1}{8}$ inches, that is a little above the basis of the cone made in sealing; when the glass bursting with a noise, the pipe remain'd entire, and a considerable part of the water appeared unfrozen under the ice, and the broken vessel seemed to smoke: and here, as we conjectured, the air was compress'd into about a twentieth part of its former dimensions.

7. The spherical part of a glass-egg, about three inches in diameter, being filled with water to the bottom of the stem, was carefully freed from air, sealed and exposed to freeze from the bottom upwards; when the water in the ball was frozen, and a small part of that in the bottom of the stem, the remaining fluid reached above $8\frac{1}{2}$ inches above the original station; while the whole length of the stem was little more than $10\frac{1}{2}$ inches. The same glass of water being afterwards sealed up with air in it, and frozen, the ice reached not quite four inches above the original station; tho' 'twas now as well frozen as before.

But these experiments seem to contradict the accounts given us, by those who have sailed in frozen seas, of huge floating mountains of ice, with their tops a surprizing height out of water, in comparison of their immerfed part. The *Dutch* tell us of one they saw in their famous voyage to *Nova Zembla*, that reached sixteen fathom above the surface of the water, and but thirty six below it.

They

PHYSICS.

They have also these two more remarkable passages in their voyage. And we saw, "say they," another great piece of ice lying fast in the sea, as if it had been a tower; we rowed up to it, and casting out our lead, found that it rested twenty fathom on the ground under water, and twelve fathom above the surface.---By casting out our lead we found another piece of ice lye eighteen fathom deep, fast at the bottom, and ten fathom high above the surface of the sea."

And *Janus Munchius* mentions some floating pieces of ice, seen in his voyage to *Greenland*, that were extant twenty fathom, whilst what remain'd of them under water was but forty; whereas, according to our computation, the immersed part of ice ought to be eight or nine times as deep as its extent is high. To obviate this objection, let it be observed, that in our computation, the ice is supposed to float in fresh water, when, in the other case, it swims in the sea, whose water is much heavier. We must, however, allow, that the sea is less salt near the poles, than in the temperate or torrid zone; but then this lesser degree of saltiness may be ballanced by a greater degree of coldness, which vehemently condenses that water, before it begins to freeze. However, the principal thing to be here considered is, that these prodigious masses of ice, are not uniformly solid, but composed of several rude portions cemented together, with huge cavities between them: and, according to *Bartholine*, chiefly consist of frozen snow; so that their weight must not be estimated by their bulk, without allowing for the air and interspersed vacuities in them; whence the whole icy mountain may press the subjacent fluid no more than a bulk of the same water equal to that of the immersed part of the ice. Moreover, 'tis very probable, that these mountains of ice would sink lower, had they a sufficient depth of water; for I find not that any pieces have been measured that floated freely in the sea; and therefore if their bottoms rest upon the ground, the great snows, frequent in gelid climates, may easily fall upon their heads, and running together by the sun's heat, &c. add to their height above water. Thus the ice observed by Captain *James*, to be twice the height of his top-mast head, rested in forty fathom water; and the large mountain above mention'd, observed by the *Hollanders* in *Nova Zembla*, lay fast in the ground. But Mr. *Hudson*, in the bay that has receiv'd his name, met with several islands of ice a-ground in six or seven score fathom water; where, if the sea had been deeper, they wou'd, doubtless, have sunk lower, and so lessened the height of their extant parts.

As no liquors have hitherto appeared to me expanded by cold, without actual freezing, 'tis a question whether aqueous fluids expand by congelation upon any other account than that of the phlegm they contain: farther experiments might, however, be made to settle this matter.

*Experiments
to discover the
expansive force
of freezing
water.*

1. The force wherewith water expands in freezing, is greater than men generally imagine. We filled a half pint pewter bottle quite full of water, screwed on its stopple, and exposed it to the cold air of a frosty night, and by next morning found the water had burst the bottle, which was new; the crack appearing in the very substance of the pewter. This experiment we repeated with the like success.

2. To try whether a small quantity of water would produce the same effect, we poured about an ounce of water into a new small and thick pewter pot; and found it constantly torn by the expansive force of the ice.

3. We, afterwards, filled a quart bottle with a congealable liquor, and tied down the cork very firmly with strong packthread; but notwithstanding this precaution, the expanding fluid forced it out.

4. We, therefore, fastened a cork still more strongly in the mouth of a quart glass bottle of water, which we exposed to an exceeding sharp air, for several hours, till, at length, the bottle burst; tho' the thinnest part where it broke measured $\frac{3}{8}$ inch. In the same manner, we, also, broke a strong earthen *Flanders* bottle, the thinnest part whereof measured, also, $\frac{3}{8}$ inch.

5. But to bring this force nearer to a computation, I made use of a strong concave brass cylinder, open at one end, which was exactly fitted with a cover, that, by its rim, filled up the mouth. This cylinder, which was five inches deep on the inside, and $1\frac{1}{4}$ inch in diameter, we filled perfectly full with water, carefully placed on the cover, fastened it into an iron frame that held it erect, and placed a small half hundred weight thereon, and thus exposed it to the cold air of a frosty night; but the contained water was found uncongealed, the next morning: and no better success had we upon a second attempt, whatever were the cause hereof. We, therefore, applied to the outside of the vessel, a mixture of ice and salt; yet, even by this means, the glaciation proceeded very slowly: but at length ice on one side swell'd above the top of the cylinder, there raised up the cover, and threw down the weight. At another time, however, we found both the cover and weight, uniformly lifted up to a small height by the expanded ice. And here we took particular notice, that the included cylinder of ice being, after a gentle thaw of its superficial parts, taken out, appeared opaque with bubbles; and when the weight was newly taken off, there issued from a little hole, that seemed to be between the ice and edge of the brass, many drops of water dilated into numerous bubbles, and reduced into a kind of froth, as if they had got liberty to expand themselves by the removal of the weight: however, this phenomenon was but of short continuance.

6. But

PHYSICS.

6. But the inconveniencies attending this method, obliged us to alter the brass cover for a well soak'd wooden plug, which, being forcibly driven into the mouth of our cylinder, could not be forced out by the weight of seventy five pound, hung thereto, while the cylinder was inverted. Water being thus exposed to freeze, in a very sharp night, thrust out the plug about the breadth of a barely corn, quite round, above the upper edge of the cylinder; but continuing to freeze for two days longer, it, at length, forced it out near a quarter of an inch. How much greater the expansive force of freezing water may be, we could not determine for want of convenient instruments wherewith to measure it; but this degree seems very extraordinary, considering water, when unconfined, extends it self, by congelation, no farther than to possess, at most, an eighth more space than when in its natural state.

7. We took a strong cylinder of brass, its cavity two inches in diameter, and placed therein a well-tied bladder, including some water, which could not expand any way but upwards; to the mouth of this cylinder we fitted a wooden plug, to rise and fall therein with ease, upon which we laid weights, to hinder its elevation when the water began to freeze; then applying salt and ice to the vessel, the water in the bladder soon began to expand it self, and, in two hours after, the plug appeared to be raised near half an inch, notwithstanding the hundred and twenty pound weight that lay thereon. Upon repeating this experiment, instead of the forementioned weight, two hundred and fifty four pounds were now elevated by the expansive force of the ice.

8. A gun-barrel, fourteen inches long, whose bore was in diameter $\frac{1}{8}$ inch, and where least thick of metal $\frac{1}{8}$ inch, being filled with water, exactly closed at the breech, and stopped a screw at the mouth, was buried in ice and salt for about two hours, and, during that time, received a crack of six inches long, that run obliquely from three inches above the breech, and appeared widest in the middle; where, also, the barrel seemed distended. The ice we thought contained smaller bubbles than if the water had not been pent up; but the smallest were so numerous as to hinder its transparency.

9. The touch hole of a strong gun-barrel, twenty four inches long, being stopped, and a plug of iron forcibly driven into the muzzle after the barrel had been filled with water, we placed it in a mixture of ice and salt, where, within about three minutes, the plug was, with a noise forcibly driven out of the mouth; and being now wedg'd and fixed in faster than before, it was, in three minutes time, again forced out with such a vehemence, that it broke a deal board of the box wherein the experiment was made. We afterwards incorporated the plug, by means of the fire and a hammer, with the muzzle of the gun; when exposing it to freeze afresh, the touch-hole gave way; and this
caused

caused us to thrust a nail into the touch-hole ; when, upon repeating the experiment, that too was driven out : but lastly, we now foldered the nail in, so that the water could not expand without bursting the barrel ; and accordingly, within a quarter of a hour after it was thus placed in the freezing mixture, it burst, with a loud noise, and blew up the cover of the box wherein it lay ; tho' the crack which was $2\frac{1}{2}$ inches long, discovered a very considerable thickness in that part of the metal.

10. A new pint, pewter bottle, filled with water, and a top screwed on to it, being set in a frigorific mixture, for a quarter of an hour, it broke, with a noise, and exhibited a crack almost $1\frac{1}{2}$ inch long, and in one place $\frac{1}{8}$ inch wide. The bottle seemed to be every way distended, but particularly at the bottom.

11. I caused a smith to take a pistol-barrel about two feet in length, and of a proportionable bore, and, by rivetting in a piece of iron, to stop exactly the touch-hole, and then fit to the mouth of the barrel a screw, to go as close as possible: this barrel being filled to the top with water ; I caused the screw to be very forcibly driven in, that the water, dilated by congelation, might neither press it out nor get between it and the top of the barrel ; and having then suspended the barrel in a perpendicular posture in the free air of a very cold night, I found, the next morning, that the water had thrust out a great part of the screw, tho' I had oil'd it before, and was got betwixt the remaning part of it and the barrel ; wherefore, the excessive cold continuing one day longer, I, the next night, caused the intervals that might be left betwixt the male and female screw, to be filled up with melted bees wax ; and having, in other points, proceeded as before, I found, the next morning, the screw held as I desired ; and that the cold had so forcibly congealed and expanded the water, that it burst the iron barrel near the top, and made a considerable oblique crack therein, about which a pretty quantity of ice appeared to stick, and also three or four other flaws or actual cracks, at some of which, smaller quantities of water appeared to have got out. When, by thawing one part of the ice, some pieces of the rest were got out of the barrel, all I took notice of appeared to be full of bubbles smaller than ordinary.

12. Moreover, we attempted to freeze water that filled a small cavity left in a thick iron ball, and cut into a female screw, whereto a male one was fitted, to be driven by means of a vice ; but any degree of cold we could procure proving unable, or not sufficiently durable to congeal the water, thro' such a thickness of metal, we cannot say what phenomena such an experiment, successfully tried, might afford.

13. But whence can this prodigious force of congealed water proceed ? Should cold be, as the *Cartesians* would have it, only a privation

PHYSICS. of heat, or freezing be occasioned, according to the *Epicureans*, by the entrance of frigorific particles, 'tis not very easy to account for this phenomenon. The first hypothesis shews no cause of this expansive power; nor does the second explain how the admitted corpuscles should produce so strange an effect, without giving any manifest signs of violence in their first admittance, when they freely penetrate the sides of the vessel they afterwards burst. Besides, in oil, which requires a great degree of cold to reduce it to a moderate hardness, the frigorific particles it admitted, do not expand, but contract it.

14. I leave it to others to make further experiments upon other aqueous liquors, as to their different degrees of expansion by cold; I am told, however, that in *Russia*, glass and stone bottles are frequently burst by the congealed beer or wine they contain.

XV.

Experiments relating to a new method of estimating the expansive force of congelation, and of highly compressing air without engines.

1. We poured water into a large glass-egg, with a proportionable cylindrical stem, till it ascended about a finger's breadth into its neck, and then set it to freeze, for some hours, in snow and salt, with the top of the tube open, whereby the water rose almost seven inches. At this time we nimbly sealed up the upper end of the tube, that was drawn out exceeding slender, and suffered it to continue in the mixture, adding fresh snow occasionally, for about twenty-four hours, to see how much the imprisoned air would be compress'd; which, at the time of sealing, was a cylinder of about $9\frac{2}{8}$ inches high. This space the upper water gradually invaded, as ice increased below, till, at length, the water reached almost $8\frac{2}{8}$ above the station it had when first the glass was sealed; and, consequently, had crowded the air into the space of about an inch. Then gently inverting the glass, that the air might come at the ice, for the water in the stem had purposely been kept fluid, we broke the sealed end into a jar, whereupon the compress'd air immediately, and with violence, blew out of the tube, about ten inches height of water, that is a greater space than was possessed by the air before condensation: and such a great multitude of bubbles were now set at liberty, that they rose from the lower part of the glass to the top of the remaining water, as in bottled beer upon taking out the cork. 'Twas here remarkable, that when the air stood compress'd to seven inches, the middle of the glass possessed thereby, and nearest to the water, was all around, to a considerable height, full of very small drops like dew, which disappear'd when we came to break the sealed end.

2. Having filled a single vial, with water, about half an inch above the lower part of the neck, and left two inches height of air in the remaining part thereof, which was, also, drawn out into a slender pipe, we sealed it up, after the air had been thoroughly cooled, and set the water to freeze; whereby the air was condensed into a less space: but soon after, the upper part and slender pipe of the glass, were

were blown off, with a considerable noise and violence. This glass, indeed, was made of brittle metal; tho' the like accident also be-
tel us in two other attempts.

3. We took a glass, in shape and magnitude like a turkey's egg, with a cylindrical stem, except that it was a little wider at the bottom than at the top, and filled it with water till only $4\frac{1}{4}$ inches of the tube remained empty; the upper part whereof was drawn conical, for the conveniency of sealing: along this tube from the surface of the water to the top of the glass, we pasted a long slip of paper, divided into inches and quarters; then sealing the glass, we observed, that by holding it in a warm hand, in a room where there was a large fire, the water rose near $\frac{1}{4}$ inch; but placing the glass among pieces of solid ice and salt, the water presently began to subside, and, freezing soon after, to swell, so that by degrees it compressed the air into above a seventeenth part of the space it before possess'd; till at length, the force of expansion growing too strong for the resistance of the glass, it burst, with a very loud noise, in its oval part; the pipe and seal'd end remaining entire; and the ice appearing full of bubbles, which render'd it opaque and white. The water that had ascended into the neck, was all driven out upon the bursting of the glass.

4. But the most successful experiment of this kind, was made in a short, strong, glass-egg, whose ball bore a very large proportion to its stem; whence the expansion might exert itself more forcibly. This vessel, furnish'd with water, we sealed exactly, placed a divided list of paper along its stem, and exposed it to freeze in ice and salt, by which means the water presently began to condense the air, ascending, for a considerable time, very fast, till it had crowded the contain'd air into a nineteenth part of the space it at first possess'd; when presently the ball of the glass was burst to pieces, with a loud report; but the stem was left entire.

5. We took a round ball of glass, furnish'd with a moderately long pipe, and having fill'd it with water, till the liquor reach'd within some inches of the top, we seal'd it hermetically; and then the water, by a mixture of ice and salt, was made to freeze from the bottom upwards; that, without breaking the glass, the unfrozen water might be impelled upwards by the expansive endeavour of that which was freezing, and so, at once, both compress the air, and be press'd upon by it: having, by this means, condensed the air, as far as we thought safe in the glass, we broke off its small apex; when immediately the compress'd air flew out with a great noise, and part of the pipe, which was unfill'd with water, appear'd fill'd with smoke, that made it look white; and great store of little bubbles hastily ascended from the lower parts of the water to the upper, where most of them quickly broke. But, what is principally to be noted, the water itself immediately ascended $\frac{3}{4}$ of an inch. Tho' I am not sure, till farther trial, that there was no springiness in the ice that contributed to the effect; or that

PHYSICS.

the great pressure of the condens'd air, did not make the glass itself stretch or yield; in which case the parts of the distended glass, upon the removal of the forcible pressure of the air, returning to their former straightness below, will make the water ascend somewhat higher in the pipe. But I cou'd not procure proper glasses wherewith to examine the truth of this suspicion; which I wou'd, likewise, have tried by the bulk of the glass in water, before and after letting out of the compress'd air. But as four or five other trials made with another liquor, as well as water, exhibited a manifest intumescence; so in the present experiment, if we had judg'd our glass strong enough to endure such a compression of the included air, as we have often employ'd on other occasions, the effect wou'd, probably, have been much more considerable. For, tho' the difference between the length of the same water, compress'd and uncompress'd, amounted to a cylinder of $\frac{1}{8}$ inch in height, yet the air that made this compression was itself reduc'd, but from eight inches to five; whereas we have sometimes reduc'd it to an eighteenth or twentieth part of its usual space. I might add, that, when we broke off the seal'd apex of the glass, before the included air was much compress'd, there wou'd be neither any great noise made, nor any considerable froth produced at the top of the water; and that having repeated the experiment in one of the same glasses, and with the same water that had been already compress'd therein, we found, upon breaking off the hermetical seal a second time, the water did, nevertheless, ascend into the pipe, betwixt $\frac{1}{8}$ and $\frac{1}{4}$ inch.

6. This method of compressing air in vessels hermetically sealed, seems less exceptionable than any hitherto put in practice; and had we not wanted freezing materials, and proper glasses, I make no question, but, we shou'd have reduced that fluid into a much less space. And, by the way, this seems a promising method, wherein to attempt the compression of water; for its having been hitherto found incompressible, may, perhaps, be owing to the porosity of the vessels employ'd, which admit the particles of the fluid to pass thro' them, upon the sudden application of any great force; whilst, in our way, the force is gradually and uniformly exerted, upon the water, in a vessel that may break indeed, but till then, remains perfectly impervious to the finest parts of the contain'd fluid. And in one of the preceding experiments, it appear'd, from the vast multitude of bubbles that manifested themselves, upon the breaking of the glass, that the water which lay between the ice and the crowded air, had been violently compress'd by them; which we rather believe, because, having at another time, sealed up some air and water in a glass-egg, and permitted the water to swell by the operation of the cold, till it had reduced the air into $\frac{1}{4}$ of its natural space, we actually perceiv'd the

water ascend, to the height of $\frac{1}{4}$ inch, upon breaking off the sealed apex of the glass.

PHYSICS.

XVI.

1. 'Tis more difficult, than one at first sight wou'd imagine, to determine the sphere of the activity of cold; for to assign the precise limits wherein a cold body can operate, many particulars must be taken into consideration: as, for instance, the degree of cold belonging to the given body; the medium thro' which its power is diffused; the consistence, texture, motion, or rest of that medium; the manner wherein the cold is spread, with regard to the instrument that acquaints us with it; the bulk of the body, &c. However, in the small portions of ice employ'd in our experiments, we found the sphere of activity very narrow; not only when compared to that of heat or fire, but the atmospheres of scented bodies, or even of the attraction in a load-stone: so that I have made it a question, whether a cold body be discernable by us without immediate contact. And agreeable hereto, I cou'd not find, if a man's eyes were close shut, that he was sensible of the nearest possible approach of a tolerably large piece of ice, to the ends of his fingers.

Experiments and observations upon the sphere of activity of cold.

2. And for farther satisfaction herein, I placed one of the most sensible thermometers very near to little masses of snow, but it took no notice of them, till we caused them to touch the instrument. This languidness in the operation may, however, chance to proceed from the smallness of the pieces of ice employ'd; for a merchant, who has made several observations upon cold in *Greenland*, informs me, that upon the sea they were apprized of their approach to ice, as well by the increase of cold, as the shining light it yields. Tho' this account, I must own, seems not to agree with that of some others, who have fail'd in frozen climates; and once, in particular, I remember it is said by some of them, that their ship lay aside of vast shoals of ice, whilst they, thro' fogs, remain'd ignorant of it. Tho' I have been inform'd by an old sea captain, that when the wind blew from the great banks and tracts of ice, they felt an extraordinary degree of cold, sometimes for twenty leagues before they came up to it.

3. We design'd to have tried, whether snow or ice wou'd freeze water, that was immediately contiguous to them; for *Olearius* relates, that at *Ispahan*, the capital city of *Persia*, where the water seldom freezes above an inch thick, and the ice presently dissolves upon the rising of the sun, there are store-houses furnish'd with thick pieces of solid ice, procured by pouring a large quantity of water, at proper intervals, over-night, upon a shelving marble floor, where, as the water runs, it is frozen by the contiguous ice; which thereby, in two or three successive nights, becomes considerably thick.

4. Once

PHYSICS.

4. Once indeed, we attempted to make this experiment in *England*, when the water, instead of freezing upon the ice, dissolved it; but then the water was fresh pump'd, and had not been suffer'd to cool in the open air, before we employ'd it; and therefore seem'd warmish in comparison of ice. And indeed, allowance must be made for the different temperature of the air of different countries: for tho' water poured upon snow, is apt to dissolve it with us; yet in *Russia*, I am inform'd, they frequently convert water and snow into ice, by mixing them together.

5. Natural glaciation, usually proceeds from the upper parts of bodies to their lower; but how deep the frost will reach in earth and water, is not easily known; because this depth may vary with the degree of coldness in the air, which appears to be the cause of glaciation, as also by a longer or shorter duration of the frost, the texture of the earth, the nature of the juices wherewith it is impregnated, the constitution of its more internal parts, as to heat and cold, the nature of its effluvia, &c. Thus, I have seen a large tract of land, with vast quantities of lime-stones near its surface, where I was assured, that snow will never lye. And to try the depth, whereto frost will penetrate into the earth, I made the following observation in a village near two miles from a great city. (1.) *Jan. 22.* After four nights of hard frost, we dug in an orchard where the ground was level and bare, and found the frost had scarce reach'd $3\frac{1}{2}$ inches; and in a garden, nearer the house, only two inches below the surface. (2.) Nine or ten successive frosty nights, froze the bare ground in the garden $6\frac{1}{2}$ inches deep, and in the orchard, where a wall shelter'd it from the south-sun, to the depth of $8\frac{1}{2}$ inches. (3.) *Feb. 9.* We dug in an orchard near a wall, and found the frost to have penetrated the ground about fourteen inches; when eight days before it was observed to be $8\frac{1}{2}$ inches. (4.) A slender glass pipe, eighteen inches long, sealed at one end, and filled with water, being thrust, over night, into a hole made in the earth, till the surface of the water lay level with that of the ground, the water appear'd, next morning, frozen in the cylinder only a little more than to the depth of three inches; but there reached downwards from this ice, part of a cylinder of the same, to the length of six inches; the rest of the water remaining unfrozen, tho' in an exceeding sharp night, and in a very hard season. The earth in the garden where this experiment was made, seem'd frozen to the depth of eight or ten inches. (5.) Upon enquiry, I find, that in the most frozen countries, a congealing degree of cold penetrates the earth and sea, nothing near so deep as is usually imagin'd. A traveller assured me, that in a garden at *Moscow*, he found the ground, in a hard season, to be frozen, but little above two feet below the surface; and the utmost effect that Capt. *James* mentions the cold to have had upon the ground in *Charlton* island, was to freeze it ten feet deep: whence may
appear

appear the different degrees of cold, of that island and *Russia*. And as to the freezing of the water there, he tells us, "it does not naturally congeal above the depth of six feet, the rest being by accident; tho' ice may be seen here six fathom thick: this we found by digging the ice out of our ship; and by digging to our anchor before the ice broke up." The same gentleman also observed, that the salt water was not here much above half so thick frozen as the earth: but fresh water has a much greater disposition to freeze, than that of the sea.

PHYSICS.

XVII.

1. In examining whether cold may be propagated thro' all mediums, universally, regard must be had to the particular medium wherein the experiment is made; for if it have too great a thickness, we may mistake by imputing to the nature of the medium, what is really owing to the distance, between the agent and patient. Thus mixtures of ice and snow will operate only at a very small distance, tho' the medium resist no more than common air.

Experiments upon the different mediums, thro' which cold may be diffused.

2. Upon placing a large quantity of the mixtures of ice and snow in pipkins glazed within-side, and in white basons, glazed both within and without; the external surfaces of both were crufted over with ice, tho' the thickness alone of the vessels seem'd to be the utmost limits of the freezing power.

3. By the experiments formerly mention'd, as to freezing water in pewter vessels, it appears, that cold is able to operate thro' them.

4. This receives farther confirmation, from the making of drinking cups of ice; the method whereof is, to take a cup made of plated iron, and tinn'd over on both sides, of any assignable size; and of the same materials, a less of the same figure to go within-side the former, so as to leave a competent space betwixt the whole internal surface of the larger, and external one of the smaller; the latter cup hanging free, by its rim upon the edge of the former, and at a considerable distance from its bottom. The interval between the two cups being fill'd with water, and the cavity of the internal one with a mixture of ice and salt, and the external surface surrounded with the same mixture, the water is hereby quickly frozen; when, the parts of the mould being disjoin'd, the icy cup is made. To prevent the ice from adhering to the mould, we sometimes anointed the latter with some unctuous material; but the best way we found, tho' it made the cup less durable, was to thaw its surfaces, gently, by heat.

5. *Bartholine* mentions an experiment to turn air, as he calls it, into water, in a hot season; by placing some snow or ice in a funnel, to condense the watery particles, floating in the air, and cause it to trickle down the sides thereof. However, upon trial with large and thick glass funnels, containing a mixture of ice and salt, we were able

PHYSICS. able to obtain only an inconsiderable quantity of water, which distilled from the ice, formed on the outside of the glass, only whilst the mixture was dissolving.

6. That a mixture of snow and salt, included in glasses hermetically sealed, condenses the vapour of the air on the outside thereof, we have already seen; from whence 'tis manifest, that the compact body of glass is pervious to cold: nor can the air be here supposed the medium that conveys it; however, we thought it proper to try, whether cold be convey'd thro' a *vacuum*, as 'tis usually call'd.

7. A small tube, sealed at one end, and almost fill'd with water, being put into a convenient receiver, which we, first thoroughly exhausted by the air-pump, and then surrounded with a mixture of ice and salt, to the height whereat the water stood in the small pipe, that water was, at length, tho' slowly, frozen from the top to the bottom, into odd kind of flakes, without any considerable number of bubbles appearing therein.

8. That cold will act thro' a medium sensibly and continually hot, appears from drinking a large quantity of cold water; which will manifest its chilliness thro' the integuments of the abdomen; as I have observed in myself upon drinking the mineral waters of *Tunbridge*: and this was, in a vehement degree, experienced by a gentleman, who drank them in a larger quantity at the same time.

9. Having with water fill'd a glass bubble, whose magnitude equall'd that of a walnut, its figure resembling that of a pear, and whose stem was crooked; we suspended it by a thread, the upper end whereof pass'd thro' a slit in a cork, and was there fasten'd, in a wide-mouthed glass filled with common oil of turpentine, and cover'd with ice and salt, and closed with the cork: thus we left all for three hours; at the end of which time, tho' the oil remain'd fluid, the water in the bubble was wholly frozen, and the bubble itself crack'd so, that only a small part of it came up with the thread; the ice wherein appear'd deeply cleft from the surface towards the centre, into two pieces easily separable; as if a pear had been cut along from its stalk thro' the core: and leaving them in the same fluid and vessel, with some thawing ice and salt about it, for fourteen or fifteen hours, they were not considerably wasted. And, by the way, along with this bubble, we exposed in the same manner, a glass-egg, whose ball, and a little part of its stem, was filled with some of the same oil of turpentine, which, thus soon subsided about half an inch; whence it deserves to be consider'd, why, if cold be caused by admission of actual particles, they shou'd contract the oil without being able to freeze it, and freeze the water without contracting, but expanding the same.

10. After the manner lately described, we suspended a small glass bubble fill'd with water, and hermetically sealed, in a glass of spirit of wine, and exposed them to the air of a cold night, whereby the water was congealed, tho' the spirit continued its natural fluidity. But another bubble of water suspended in common brine, at the same time with the former, was no more frozen than the brine itself, that is, not at all. The same success, also, attended the repetition of this experiment twice; however, upon a fourth trial, we found the bubble burst, within two hours after it had been exposed in a mixture of ice and salt, with ice adhering to the upper part of the bubble, whilst the other was crack'd, in lines that run from a point. And more ice, we supposed, would have appear'd, had it not been dissolved by the salt water, getting in at these cracks.

11. We fill'd a small glass-bubble with fair water, sealed it hermetically, and suspended it in the middle of a large empty wide-mouth'd glass well stop'd; then exposing it to a sufficient degree of cold, we found that the water froze, and crack'd the bubble, without the intervention of any visible liquor.

XVIII.

1. We are inform'd, that to the inhabitants of some parts of the *East-Indies*, it has appear'd a thing incredible, that the fluid body of water shou'd, in a few hours time, be naturally converted into a solid. This, thro' its commonness, appears little astonishing to us; however the degrees of cohesion in the parts of ice, have not been settled; nor perhaps can we arrive any higher than a bare conjecture in this particular: for different degrees of cold, may possibly give different degrees of compactness thereto; and accordingly, I have been assured, that the ice in *Russia*, is much harder than in *England*.

*Experiments
and observa-
tions upon ice.*

2. I have had thoughts of several methods to estimate the cohesion of the parts of ice; and pursued the matter far enough to satisfy myself, that its ability to support a weight is surprizingly great, considering that common knives will easily cut it.

3. We placed a piece of ice, three inches long, three broad, and less than $\frac{1}{4}$ inch thick, cross-wise on a frame; so that the two parts whereon the ice rested, were distant near three inches from each other; then fixing a scale to an iron hook, we hung it in the middle of the ice, and lay'd weights thereon, till the hook, whose part that rested on the ice was $\frac{1}{8}$ inch, forced itself downwards, and, at length, the ice broke, the hook having first descended half thro' the ice at one end, and a third part thro' it at the other, of the incision. The weight applied was seventeen pounds averdupoize, and one hundred seventeen ounces troy.

4. This experiment we repeated with a piece of ice $2\frac{1}{2}$ inches broad, and $\frac{1}{4}$ inch thick, placed in the frame at the distance above-men-

PHYSICS.

tion'd; but the weight required to break it, was seventeen pounds averdupoize, and forty eight ounces troy. The horizontal part of the hook had, however, cut more than $\frac{2}{3}$ thro' the ice at one end, and nearly half thro' at the other.

5. We have found, that by strewing bay-salt upon thin plates of ice, placed on a flat board, the ice wou'd, in some measure, be dissolved, and afterwards so strongly frozen to the board, that we were obliged to beat it off piece-meal, with an iron instrument, if we wou'd disjoin them; nay, the parts of ice adhered so firmly in the pores of wood, that some of them, notwithstanding this force, still continued unmoved.

6. Having thrown a considerable quantity of salt upon some solid pieces of ice, there was suddenly produced a small crackling noise; and for a considerable time after, there manifestly ascended a large white steam, or thick smoke therefrom.

7. Upon pouring *Aqua fortis* on cakes of ice, wherein was abundance of bubbles, it presently penetrated thro' them with a considerable noise, that seem'd to be the cracking of the ice, whilst the liquor underneath it, might be tasted manifestly sour. Oil of vitriol, also, afforded the same phenomena, but in a much greater degree, yet without seeming to crack the ice it pass'd thro'; so that if only a few drops hereof were let fall, it immediately shew'd itself exceeding corrosive on the opposite side of the ice: and this we found it wou'd do thro' three plates of ice, lay'd one upon another, each whereof was about $\frac{1}{8}$ inch in thickness.

8. Decoctions of sage, rosemary and parsley, being severally exposed, in small earthen pipkins, to freeze, they were totally converted into ice, wherein appear'd no resemblance of the respective plants; only that afforded by the decoction of sage, had a very uneven surface, and far more rugged than the other two, which were neither of them smooth; and all of them, but particularly the decoction of sage, yielded a softer ice than the common.

9. Some fresh lemmon juice, froze in a wide-mouthed glass, afforded an ice very odly figured, especially in one part, where it finely represented naked trees.

10. Snow-water set to freeze in ice and salt, afforded pretty figures in its congelation, with bubbles produced therein, so minute, that the whole mass of ice remain'd very transparent.

11. Upon mixing a large quantity of ice in gross powder, with some whole bay salt, and stirring them together, a visible fume overspread the containing vessel, like a fog; and when risen above its brim, fell down again in streams: these fumes also play'd in great plenty upon the surface of the mixture, as a mist upon a pond, being some of them unable to rise higher. The phenomenon continued for a long time, tho' I cou'd not be positive, that these fumes were cold;

cold; however, a thermometer applied to them, seem'd to subside a little.

12. *Olaus Magnus* tells us, "that the ice in the cold northern climates, about the beginning and middle of winter, has its cohesion of parts so strong, that at the thickness of two inches, it will support a man; at the thickness of three, an armed dragoon; at that of fourteen, a company or band of soldiers; and, lastly, that if it be a yard thick, an army, of ten thousand men, may march thereon." This indeed, is no accurate way of measuring the cohesive force of ice; because the distance of the part that supports the weight, from the shoar, is not here regarded, tho' the remoter parts of the ice rest hereon; for the ice being consider'd as a lever, the place of the weight upon it, must, by all means, be determined; since the ice may resist a considerable pressure near the banks, tho' but a very small one near the middle of a frozen river. However, 'tis plain from this general observation, that the ice of a river, at such a particular thickness, will in any part of it, sustain the respective weights above-mention'd; and therefore, even at a point, the farthest removed from the prop of the lever; which shews an immense force of cohesion in ice.

13. I proceed to the observations of travellers and sailors, made upon ice. Capt. *Weymouth* tells us, that, in his voyage to discover the north-west passage, he found ice almost as hard as a rock. He relates farther, "that finding some pieces broken off from an island of ice, they afforded very good fresh water." An old sea captain, who had often sailed into the frigid zone, assured me, that when his ship had been immured with ice, so that no salt-water cou'd be come at, he made wells in thick pieces of ice to receive the liquor that thaw'd therein, which he found, tho' on the main sea, to be good, fresh, potable water, and fit for all necessary uses; so that he never fear'd the want of such water there. There's a possibility, however, that this ice, which affords fresh water in the sea, is congealed snow, (not the salt-water frozen) that lies upon the surface, and adds to the height of the ice underneath; 'tis also possible, that such ice may have come from rivers that discharge themselves into the sea, as those vast quantities observed about *Nova Zembla*, and the streights of *Weigats* are allow'd to descend from the great rivers *Oby*, *Jenesce*, &c. and this carries the greater possibility, because the main sea is seldom or never frozen.

14. The next thing I shall consider is, the magnitude of single portions of ice. The old sea captain above-mention'd told me, he several times fasten'd his ship to masses of ice, that reach'd thirty fathom under water; and that he once lay aside of a piece that rested on ground in fifty fathom water. None of these, he said, rose with their heads very high above the seas surface; he thought not much more than

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a tenth

PHYSICS. a tenth part of their whole length; and that snow, successively falling thereon, depress'd them so low; which often melting within two or three days, wou'd subside to a third or fourth part of its former height, and become solid ice. Capt. *James* tells us, he one day sailed by an icy mountain of a height incredibly greater than what we lately observed from him, to be taller than his main-mast. But the famous sailor Mr. *Baffin* says, "on the seventeenth of May, we sailed by many great islands of ice, that were above two hundred feet high above water; and one in particular, that I measured to be two hundred and forty feet; whence if only $\frac{1}{2}$ of the ice be extant above the surface of the sea, this piece of ice must have been one hundred forty fathom long; and this proportion, I have known to hold in some ice; but I don't affirm it in all." Capt. *James* observed some flat pieces of ice, to measure one thousand of his paces in length.

15. Of compounded portions of ice, I find the following accounts. Mr. *Hall*, in his voyage to discover *Greenland*, tells us, he met with an huge bank of ice twenty four miles long. Another *English* sailor relates, "that, even in *June*, the sea where he lay, was cover'd with ice, as far as he cou'd discern all around him, from a considerable eminence, except within a quarter of a mile from the shoar." Whence that vast extent of ice shou'd appear as one floating island. The *French* hydrographer *Fournier*, relates, "that their fleet sailing to *Canada*, in the year 1635, met with several masses of ice, as high as steeples; and in particular, one or two, in some places being flat, and in others, rising up in frightful hills, along which they coasted, for above forty, or even eighty leagues together; and here, says he," are often, in the month of *August*, seen floating pieces of ice much larger than ships." *Olaus Magnus* assures us, "that battles are fought as well upon the ice of the northern seas, where, during the summer, fleets usually engage, as upon solid champaign ground; let the contending armies, with all their artillery, be drawn up ever so close together." And 'tis a common thing in the more northern nations to take large journeys, with heavy carriages, over the vast plains of ice. 'Tis well known also, that the whole *Swedish* army lately marched over the frozen sea to the island of *Zealand*. Nay, even in the eastern regions, the sea itself has been congealed to a prodigious breadth. "*Manasses*, in his annals," says *Bartholine*, "relates it as an extraordinary thing, that in the reign of *Theophilus*, there happen'd so hard a winter, that it there froze the sea into ice, to a vast thickness, and a stony hardness." And according to *Glycas*, "in the year 775, the sea was frozen along the mediterranean coasts, to the distance of fifty leagues, into ice as hard as a rock, and to the depth of thirty cubits; at which time, also, there fell so large a quantity of snow, that added thirty cubits to the height of the ice."

16. We come now to miscellaneous observations upon ice. The Dutch, in their famous voyage to *Nova Zembla*, observed some peculiarities in a huge piece of ice, under which they shelter'd themselves from stormy winds; they tell us, it was cover'd on the top with earth; that they found forty eggs thereon; that its colour was a perfect azure; whence some of their crew affirm'd it to be frozen land; for it lay ten fathom high above the water, and descended eighteen fathom under it, that is, quite to the bottom. This colour in ice has been also observed by Capt. *James*; so that perhaps *Virgil* might not speak improperly, when he gave the epithet blue, to the ice of the frigid zone. 'Tis very considerable, if true, what *Olaus Magnus* says, "that when, towards the beginning of *April*, the ice begins to thaw, 'tis very unsafe to venture upon it, unless in a morning; for the heat of the sun renders it so brittle, that tho' it lately supported armed dragoons, a naked man can now scarce walk upon it." He adds, "that when the ice breaks, it makes a very loud and dreadful noise, like that of thunder, or an earth-quake; but especially, if it happens in the night." And to this particular, Mr. *Hall* agrees, who tells us, that, "as they steer'd by a huge, and high island of ice, there fell a piece from the top thereof, with a report equal to that of five canons; and that about twelve of the clock one night, they were suddenly compass'd round with great islands of ice, that made a most surprizing hideous noise." There are many concurring testimonies given of this noise occasion'd by ice, tho' it sometimes seems to proceed from the dashing of the pieces one against another; but if it happens at the time the ice appears to cleave spontaneously, it seems difficult to assign its cause. *Olaus Magnus*, indeed, with some probability, assigns it to the warm exhalations of the earth; and agreeably hereto, I remember, that some pieces of thick ice being brought out of a cool place into a warm room, made a small crackling noise. I am informed, however, by a native of *Poland*, that great cracks and loud frightful noises, happen as well by the action of excessive cold, as a thawing heat upon the ice. And indeed, we sometimes observe the ground to be cleft in very violent frosty weather. The old sea captain, whose testimony I have twice used already, remarks, that large tracts of ice have a power to deaden the wind; for that having been distress'd by stormy weather, and driven near huge shoals thereof, he had unexpectedly found a calm, to his great surprize; and several times sailing from the ice upon a smooth sea, he has met a storm at some distance from the same. He adds, that a Dutch sailor, who frequented the northern seas, assured him of having several times observed the like wonderful property of the ice.

Experiments
and observations
upon the
duration of ice
and snow, and
the destruction
thereof by air
and several
liquors.

1. 'Tis generally thought there are liquors potentially hot, wherein ice will sooner dissolve than in water. To bring this to the test of experiment, we attempted to freeze water in bullet-moulds, that we might gain pieces of ice exactly of the same magnitude; but not being able to procure any moulds, whose cavities were of equal dimensions, we substituted a glass tube in their stead; wherein having frozen some water into a cylinder of ice, we divided it exactly into equal portions. These pieces we severally put into different liquors at the same time, whilst exact notice was taken, by means of a second pendulum, furnished with an index, and a divided dial-plate, how long they were in dissolving.

Two sets of our experiments, were made with cylinders of ice an inch long, and about half an inch in diameter, wherein we observed as follows.

In	{	Oil of vitriol	{	the ice dissolved in	{	5	} minutes.
		Spirit of wine				12	
		Aqua fortis				12½	
		Water				12	
		Oil of turpentine				44	
		Air				64	
In	{	Oil of vitriol	{	the ice dissolved in	{	3	} minutes.
		Spirit of wine				13	
		Water				26	
		Oil of turpentine				47	
		Sallet-oil				52	
		Air				152	

2. We moreover thought it worth trying, what difference there would be in the duration of pieces of ice of the same bulk and figure, some whereof were made from water, others from wine, milk, oil, urine, &c. when exposed to thaw in the air, or other fluids; and also whether motion would impart heat to ice, by rubbing two pieces thereof one against the other: and indeed, I found such an attrition hasten the dissolution in that part of a plate of ice, which sustain'd it.

3. And, by the way, upon throwing ice into a certain cold liquor, it has presently dissolved, and produced a great degree of heat.

4. The effects of cold do not always depend upon the actual presence of its manifest efficient; for when these have once brought a disposed subject to a state of congelation, it will, sometimes, continue therein, tho' the operation ceases. And, we frequently see that when a certain texture is produced in a body, it remains there till some other agent over-powers and removes it. Tho' ice and snow may seem to melt away
of

of themselves upon the cessation of frosty weather, yet the cause of their dissolution appears to be the action of the air upon them, that is heated by the sun's rays, or some warm exhalations from the earth; and, accordingly, we see that great compacted masses of them, will, above ground, remain long undissolved, when the warm air has not free admission into the pores thereof; but if close piled up in proper repositories below the surface of the earth, they may be preserved for a still longer time. *

The method of making repositories, and preserving snow in *Italy*, take as follows, from Mr. *Evelin*. "The snow-pits in *Italy* are sunk in the most solitary places, and usually at the foot of a hill, to protect them from the sun, fifty feet deep, in form of an inverted truncate cone, with their mouth, twenty five in diameter. The sides of the pit are so joiced that the boards may be nailed very close thereon. About a yard from the bottom is fixed a strong frame, upon which is placed a kind of a wooden grate. The cover of the mouth is double thatched, with reed or straw, upon a copped roof, on one side whereof, appears a thatched narrow door-case; hipped on like the top of a dormer, which compleats the whole. To preserve their snow herein, they lay clean straw upon the grate, to prevent its running thro' whilst they beat it to a hard icy cake near a foot thick; upon which a layer of straw being laid, they place more snow thereon, and a straw upon this; and thus continue layer upon layer, till the pit be filled: when they cover the whole, thick, with straw or reed, and shut the door. The grate is contrived to drain off the liquor that might run from the snow, if by accident any should melt, which would, otherwise, hasten the dissolution of the rest; and upon this account the bottom is but slightly steen'd. The curious preserve a circle of tall, shady trees, about the mouth of the pit."

5. The *Dutch* relate, that in their *Nova Zembla* voyage, tho' the weather proved fair and sun-shiny, yet the heat was not strong enough to melt the snow on the twenty third of *June*. Nay, in warmer climates, snow will remain, during the whole summer season, undissolved upon the tops of high mountains. And Captain *James* says, that "in *July* and the beginning of *August*, we exposed some pieces of ice, that measured two feet square, to the heat of the sun in the ship's boat; whereon the rays played strongly; yet, notwithstanding that, and the warmth of the ship, wherein we kept a large fire, they lay eight or ten days before they would melt." He farther observes, that "the ground continued frozen till *June*, tho' the weather was then hot upon the shoar." The same person also relates, that a but of wine, which stood all the winter upon deck, continued firm frozen till the month of *May*.

* 'Tis a remarkable observation of M. *Homburg*, that ice in summer dissolves much sooner in *Vacuo*; than in open air. *Hist. de l'Academ.* A. 1708. p. 26.

Considerations
and experi-
ments upon the
Primum
Frigidum.

1. The dispute about the *Primum Frigidum* is become famous among naturalists; some contending it is the earth, others the air, and some of the moderns, that it is nitre; but all seem to agree that there is some particular body superlatively cold in its own nature, by partaking whereof, all other cold bodies obtain that quality.

2. But, in my opinion, before men had so deeply engaged in this dispute, they should have enquired whether there were any such thing as a *Primum Frigidum*; for tho' I will not resolutely deny its existence, yet, I think it may well be questioned, and that upon several accounts.

And first, it is very disputable, whether cold be a positive quality, or a bare privation of heat; and till this question can be determined, it must seem improper to enquire which is the *Primum Frigidum*.

'Tis, indeed, generally taken for granted, that heat, moisture, dryness, gravity, &c. have each of them a principal subject to reside in, yet this seems to be only a groundless fancy; for there are many qualities, as gravity, figure, motion, colour, sound, &c. of which no true and genuine primary subject is assignable: and since heat and cold are look'd upon as qualities diametrically opposite, it will be very hard to shew that there is a *πρῶτον ψυχρὸν*, of the former; since stones, metals, plants, animals, and almost all solid bodies, will, by motion, become hot.

Among the bodies generally alledged for this purpose, there is not one that seems to deserve the title of *Primum Frigidum*. Plutarch supposes the earth to be the *Primum Frigidum*; yet we see the earth is frozen not by its own cold, but thro' its vicinity to the air; for the congealing cold, even in the midst of winter, affects only its surface where it borders on the air, and seldom penetrates above a few feet into its substance; and, therefore, if the earth be any way protected from the air, it will remain unfrozen all the winter long; as may appear from that remarkable practice in the great salt-marshes of the French Islands of *Xaintonge*, where, when the season of coagulating salt by the heat of the sun is past, the owners, by opening certain sluices, overflow all the banks and dams that divide the salt-ponds; for if they left their works uncovered, the frost would make a great havock among them.

Besides, the earth, upon this supposition, being the coldest, as it is the heaviest and most solid of the elements, it is improbable that those excessively cold agents, that freeze the clouds into snow and hail, should be terrestrial exhalations. And 'tis not easy to say, why, if elementary corpuscles, steaming from the earth, have such a congealing power where they are disunited, and barely interspersed among the particles of air, the mass of the earth it self, from whence those exhalations are supposed to proceed, should not be able also to freeze water.

Another

Another argument against the earth's being the *Primum Frigidum*, may be taken from the subterranean fires which break out in many places of the earth; from whence some would shew, the earth to be, naturally, neither hot nor cold. And even where there appear no manifest signs of these fires, persons, who descend to the bottom of deep mines, have complained that a very little exercise would put them into a violent sweat: and the learned *M. de Claves*, who hath written of precious stones, affirms, that in such mines, the subterranean vapours are so thick and hot, that the miners are obliged to work in their shirts. I am not, however, satisfied, that those deep places would have appeared as hot, when judged of by a sealed weather-glass, as they did to the miners bodies; tho' the possessor of a lead mine assured me, he did not usually find any difficulty of breathing therein, notwithstanding the same disposition to sweat; and others, also, have not complained of having their respiration incommoded in such places, unless by accidental damps: and the author lately mention'd, expressly affirms, that the same effect is observed, in the bowels of the earth, as well in summer as in winter. Besides, 'tis generally found, that very deep wells and springs freeze not; but the water often comes up smoaking from thence: which argues that, at least, the earth wherein it lay, or thro' which it pass'd, was free from such a degree of cold, as might be expected if the earth were the *Primum Frigidum*. Nor can it be reasonably pretended, that the subterranean heat, proceeds from the rays of the sun; since they heat not the earth above six or seven feet deep, even in southern countries. And if the lower part of the earth were, of its own nature, cold, and receiv'd the heat it affords, only from the sun and stars; the deeper men descend therein, the less degree of heat and steams they would meet with; which is contrary to our *French* author's observation.

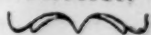
Morinus, another *French* author, who had the curiosity to descend himself into the mines of *Hungary*, some of which are three or four hundred fathom deep, relates, that after he had descended about an hundred fathom, he came into a very warm region of the earth, which lasted to the bottom of the mine; and is so hot, both in winter and summer, that the labourers usually work therein without their clothes: he adds, that himself was scarce able to bear the heat, tho' the external air was very hot; it being fair weather, and in the month of *July*. And he farther declares, he was told by the overseers, that, 'twas universal, the lower they descend, beyond a hundred fathom, the hotter it grows. But having, my self, been to the bottom of some mines, I suspect, that this degree of heat, observ'd in the *Hungarian* mines, might, in great part, proceed from the peculiar nature of the place, or of the minerals generated there; and not wholly from their vast depth beneath the surface of the earth. For, several mixtures of bodies, not actually hot, will produce a considerable

PHYSICS.

degrec of heat. And very credible eye-witnesſes have affirmed, that, in ſome parts of *England*, they dig up large quantities of a kind of mineral, ſuppoſed to be vitriolic, which, by the bare addition of common water, will grow ſo hot as almoſt to take fire. So that the *Hungarian* mines being deep, and not deſtitute of water, it may be ſuſpected, that either this fluid, or ſome peculiar mineral ſpirit, or juice, may, with the mineral, produce a warm ſteam, which, for want of ſufficient vent, in thoſe cloſe places, yield a conſiderable heat. And this conjecture may be countenanced by three circumſtances; which I take notice of in our authors narrative. For firſt, the ſmoke that plentifully aſcended out of the mine, thro' the perpendicular groove, conſiſted of fetid exhalations, which were ſo ſaline and fretting, as frequently to corrode and ſpoil the wooden ladders, and the iron inſtruments of the diggers. Secondly, the overſeers of the mines told *Morinus*, that they, in ſome places, met with veins of hot minerals, which augmented the heat of the place. And laſtly, as our author deſcended into the gold-mine at *Cremnitz*, he found in one place, the heat to increaſe gradually, and, at length, to exceed what he had met with in any other mine; and afterwards, coming into a ſpacious room, that abounded with ſmaragdine vitriol, from whence this heat proceeded, he found, beſides a ſharp ſpirit, very offensive to his throat, a heat that made him ready to faint away with ſweating. And, elſewhere, the ſame author remarks, that ſuch hot mines of vitriol, or ſulphur, may be found, even near the ſurface of the earth, and diſſuſe a heat all around, to a very great diſtance.

But if it be objected, that this ſubterranean heat is adventitious to the earth, which remains ſuperlatively cold of its own nature; it may be reply'd, 'tis ſomewhat ſtrange, that nature ſhould have intended the earth for the *Summum Frigidum*, and yet a great part thereof be conſtantly kept warm, either by the ſun, as under the torrid zone, or by ſubterranean fires.

But if it be pretended, that when the earth is ſaid to be the *Primum Frigidum*, not the elementary earth, but ſome body mixed with it, is thereby meant, I deſire to know which of the many bodies that make up the terreſtrial globe, muſt be fixed upon for this purpoſe, that we may examine its claim; in the mean time, I conclude, that the earth has none ſuch; ſince, upon this ſuppoſition, a colder body, than that is allowed to be, gives it the greateſt degrees of coldneſs it can poſſeſs. I muſt, however, diſſent from the learned *Gaſſendus*, in thinking the earth to be naturally no more cold than hot. For its inſenſible parts, like thoſe of other firm bodies, being heavy, and perhaps groſs, and either having no conſtant motion, or, at leaſt, a far more gentle one than our organs of ſenſe; it ſhould follow, that the earth muſt ſeem cold to us, unleſs it be, ſome way or other, put into an unnatural degree of agitation: and, for the like reaſon it's not improbable that



that pure earth, should, in its own nature, be colder either than pure water or pure air; since the earth being a solid body, its component particles are at rest among themselves, or, at least, mov'd with an almost infinite slowness; whilst water and air, being fluids, their component particles must be in a different, restless motion, and, consequently hotter; that is, in a state wherein the various agitations of their more minute particles is more vehement.

And if those who plead for the earth in this case, had declared they mean not the pure or elementary earth, but part of the terrestrial globe, distinguished from the sea and other waters; and would also have earth, in this sense, to be only the *Summum Frigidum*; perhaps they might have a better plea for their opinion, than those who contend for the water or the air; since the *Dutch*, who failed thrice to *Nova Zembla*, and once wintered there, affirm, that the highest degrees of cold, are not to be met with on the main sea, which is most exposed to the operation of the air and water, but either upon land or near it.

And *Fournier* tells us, that "in the year 1595, the *Hollanders*, being intercepted by icy shoals, in the straits of *Weigats*, and meeting with some *Muscovites*, were told by them, that neither the northern sea, nor that of *Tartary*, were ever froze, but only that strait, and the sea contiguous to the shores of some bays and gulphs," and our author affirms, in general terms, that the main seas never freeze.

On the contrary, I have been told, that in *Siberia*, a northern province of *Russia*, the ground is thaw'd, during the summer, only about two feet deep, whilst it still continues frozen below; tho', by the way, there, notwithstanding, grows good corn on the surface.

That water should be the *Primum Frigidum*, is contrary to experience. For, not to mention how very difficult it would be to prove that abundance of cold bodies, as gold, silver, crystal, fusible stones, &c. contain any water; nor to urge the arguments that some contenders for the superlative coldness of the air employ, I shall content myself with this obvious phenomenon of cold, that in receptacles of water, congelation begins at the surface, where the fluid is exposed to the immediate contact of the air. Now, this sufficiently argues that the air is colder than the water; since it is able not only sensibly to refrigerate, but deprive it of its fluidity; whilst, if the water itself were the *Primum Frigidum*, it either ought to be always congealed, or we may justly demand why the glaciation thereof, should not begin in the middle, or at the bottom, as soon as at the top.

'Tis a received tradition, indeed, among the water-men, and some others, that the rivers and ponds, also, are frozen, first at the bottom, and begin to thaw there. But, 'tis evident, that in water exposed to freeze, in large vessels, the congelation begins at the upper surface, and thence, as the cold prevails, the ice increases and thickens down-

PHYSICS.

wards; and for this reason, frogs retire, in frosty weather, to the bottom of ditches, whence I have taken many of them, very brisk and vigorous, from under the thick ice that covered the water: and I have been inform'd, by an observing person, that, at least, in some places, 'tis usual, in winter, for shoals of fish to retire to those depths of the sea, and rivers, where they are not to be found in summer. But if rivers were frozen first at the bottom, we must, very frequently, meet, in the emerging pieces of ice, the shapes of those irregular cavities and protuberances that are often seen in the uneven soils over which rivers take their course; yet those pieces of ice are generally flat, as if generated on the surface of the water. Moreover, if even deep rivers freeze first at the bottom, why should not springs and wells freeze first at the bottom too? But that which deceives our water-men, is, they frequently observe flakes of ice ascend from the bottom of rivers to the top, where, it often happens, that after a hard frost has continued a while, these emerging pieces of ice, contribute greatly to the freezing over of rivers; for, coming in some of the narrower parts of them, to be stopped by the superficial ice, that reaches on each side of the river, far from the banks, towards the middle; those flat icy bodies are easily cemented by the violence of the cold, and, by means of the contiguous water, to one another; and so, by degrees, freighting, and, at length, choaking up the passage, they stop the other flakes of ice, that either emerging from the bottom, or loosened from the banks of the river, are carried down the stream towards them; and those being also, by the same cold, cemented to the rest, the river is, at length, quite frozen over. And the reason why so many flakes of ice come from the bottom of the river, seems to be, that, after the water has been frozen, all along, near the banks, either the warmth of the sun, or some other accident, thawing the ground, or otherwise, loosening many pieces of ice, together with the earth stones, &c. whereto they adhere, from the more stable parts of the banks, these heavy bodies carry down with them the ice wherein they lie; but then the water at the bottom of the river being warm, in comparison of the air, in frosty weather, the ice, by degrees, is so dissolved in those parts, by which it held to the stones, earth, or other heavy bodies, that the remaining portion, being specifically lighter than water, gets loose, emerges, and, perhaps, carries up with it stones and clods of earth, that may yet stick thereto, or be inclosed therein; the sight whereof persuades the water-men, that such flakes of ice were generated at the bottom of the river; tho' a large piece of ice may buoy up and support bodies, of that kind, of a great bigness, provided the ice and they together, exceed not the weight of an equal bulk of water. Thus Captain *James Hall* relates, that upon a large piece of ice in the sea, they found a stone which they judg'd to be three hundred pound weight.

Besides,

Experiments and Observations upon Cold.

645

PHYSICS.

Besides, the frost is usually hardest when the air is clear and freed from aqueous vapours ; but the cold is more remiss in rainy weather. And to this we may add, what was lately observed of the perpetual fluidity of the main sea, and of the overflowing the salt-works in *France* ; from whence the water seems not disposed to receive any very intense degree of cold at a considerable distance from the air : for we formerly observed, that the congealing cold penetrates nothing near so deep as the thickness of some pieces of ice found in the sea, might lead one to suspect ; these being only masses form'd of many flakes and fragments, which running upon or sliding under one another, are, by the congelation of the intercepted water, cemented together into a bulk misshapen and unweildy. Thus Captain *James* informs us, that " it seldom rains in *Charlton* Island after the middle of *September*, but " snows : and the snow, " says he, " will not melt either on the shore " or sands : when it snows at low-water, the sands are all covered " over with it, which the half-tide carries off into the great bay ; and " every low water the sands are left clear : thus it daily gathers, " till the latter end of *October* ; and by that time, it renders the " seas so cold, that as the snow falls, it lies on the water in flakes, " without changing its colour ; but as the winter comes on, it begins " to freeze upon the surface three inches, or more, in one night ; " which being carried away by the half-tide, it meets with some obstacle, and then runs upon it self, so that in a few hours, it will " be five or six feet thick : the half-tide still flowing, carries it off " so fast, that by *December*, it is grown to an infinite quantity of ice." And the famous Mr. *Hudson* says, " there are prodigious shoals of " ice in the sea towards the pole ; many sounds and rivers being in " the lands of *Nova Zembla* and *Newland* to ingender it ; besides the " coast of *Pecora*, *Russia*, *Greenland*, &c."

I cannot, however, imagine, that water is indifferent as to heat and cold ; for, bating the heat of the sun, which is only adventitious where it operates, and which leaves many vast portions of water untouched ; the insensible parts of that fluid are much less agitated than those of our organs, and consequently may, in regard thereto, be judged cold : for tho' water be allowed a various motion of its component parts, yet an agitation sufficient for fluidity, is often much more slow than that of the spirits, blood, and other fluids of a human body. Thus, tho' urine continues fluid, after being long evacuated, yet its parts are far less agitated than when it came fresh out of the bladder. Nay, the whole body of the sea is very cold at any considerable depth, as a professed diver told me ; and, particularly, he said, that having occasion once to descend about twelve or fourteen fathom deep near the northern coast, tho' his engine very well supplied air for respiration, and tho' he felt no other inconveniencies, yet the cold was so violent, that he could not bear it for above two or three hours. I have often

ten

PHYSICS.

ten wished, indeed, that he had then been provided with a thermometer, to shew whether the intense cold he felt were real, or chiefly regarded his body in that state. But this is not the only person who has found the sea exceeding cold; for *Beguinus* relates the same thing from the mouth of an overseer of the coral-fishery, in the kingdom of *Tunis*. And *Josephus Acosta* tells us "it is remarkable, that in " the depth of the ocean, the water cannot be heated by the " violence of the sun, as in rivers. Nay, " says he, " as salt-petre, " tho' it be of the nature of salt, hath the property to cool water, so " we see, that, in some parts, salt-water hath the faculty of refreshing; which we observed in that of *Callao*, where they put their " wine into the sea to cool it; whence it appears that the ocean may temper " and moderate excessive heat; and upon this account " adds he " we " feel greater heat at land, *ceteris paribus*, than at sea; and find countries " lying near the sea to be cooler, than those that are farther from " it." Upon the whole, it appears, that both in very cold and very hot regions, the deep parts of the sea are very cold, the sun-beams being unable to penetrate to any great depth therein; and accordingly the diver, lately mentioned, told me, he could not discern the light of the sun at any great distance from the surface of the water; but that as he gradually descended deeper, he found it grew darker, to such a degree, as would scarce have been expected in so transparent a body as water. But this coldness of the sea is not intense enough to entitle water to the appellation of the *Primum Frigidum*; since divers have not found it sufficiently cold to freeze the water at the bottom, as the air often does at the top.

The next opinion we are to consider, is that of those, who suppose the air to be the *Primum Frigidum*.

Now, not to mention that the air is often reckoned among the hot elements; that its heat is very great in the torrid zone; nor that, according to the generality of philosophers, the upper region, which is incomparably the greatest part of it, always remains hot, and the lower region, also, in comparison of the middle; I observe, that 'tis not easie to shew how the great cold in the lower parts of the sea, proceeds from that of the air, whose operation seems not to reach very far beneath the surface of the water. For Captain *James*, who had very good opportunity to try it, allows not the frost to penetrate above two yards perpendicularly downwards from the surface of the water, even in the coldest habitable regions. And this seems the more rational, by considering, that in case the coldness of the sea proceeded constantly from the air, the cold would be greater near the surface, where 'tis contiguous to the air, than in the parts remote from it; and yet the contrary has been made appear already.

But if it be objected, that this proves no more than that the air is not the *Primum Frigidum*, and that it may still be the *Summum Frigidum*; because

because water begins to freeze at the top, where 'tis exposed to the air; to this vulgar experiment, I oppose that of mine, often, already, mention'd; wherein, by an application of salt and snow, water comes to freeze from the bottom, or any side, at pleasure; and that too, much sooner than the air would, even in a sharp frosty night. And when exceeding cold weather had reduced a parcel of air, purposely included in a convenient glass, to as great a degree of condensation, as it possibly could; I have, by an external application, condensed it much farther; which argues that 'tis not mere air, but some adventitious frigorific particles, sometimes mingled therewith, that produce, or occasion, the most remarkable degrees of cold. And thus, by a due application, water will be congealed, whether air touches the surface thereof or not; or tho' bodies, which the air can neither penetrate nor congeal, interpose; as may appear by the experiments formerly mentioned of freezing water included in glass-bubbles, and suspended in oil of turpentine, &c. And it is, here, worth observing, by those who suppose air to be the *Primum Frigidum*, because water begins to freeze at the top, where 'tis contiguous to the air; that it is there, also, where the ice begins to thaw.

Besides the three opinions hitherto examined, there is a fourth, attributed to *Gassendus*, that deserves to be seriously considered. This supposes the congelation of liquors, and the cold in air, water, &c. to proceed from nitrous particles, or exhalations, mixed therewith: but I cannot allow nitre to be the grand universal efficient of cold. 'Tis true, salt-petre seems to be one of those bodies that are endued with a refrigerating power, and is plentifully dispersed thro' several portions of the earth; but, perhaps, there may be several other causes of cold, and several other bodies qualified for its efficient.

And first, if cold be not a positive quality, but the absence of heat, the removal of caloric agents will, in many cases, suffice to produce cold, without the introduction of any nitrous particles into the body to be refrigerated. But because 'tis disputable, whether cold be a positive quality, or no, we urge this argument no farther, till that controversy be decided.

Secondly, I see no reason why the great cold we have mention'd to be met with in the depth of the ocean, shou'd be the effect of nitrous atoms, which must certainly swarm in prodigious multitudes, to refrigerate every sensible particle of the sea. Besides, 'tis not known, that nitre, especially, in vast quantities, reaches near so deep in the earth, as those parts of the sea which are found to be exceeding cold. And as the more subtle part of nitre is more dispos'd to fly up into the air, than dive down into the sea, so we find no signs of its grosser and more sensible parts abounding in the sea-water; since, upon evaporations thereof, it leaves no salt-petre behind it. But these considerations are not all that weigh with me.

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PHYSICS.

For, thirdly, I am not satisfied with what is alledg'd to prove, that the air, and adjacent parts of the earth and water, receive their highest degrees of cold from nitre. For tho' *Gassendus*, with others, says, 'tis nitre resolv'd into exhalations that makes the gelid wind, which refrigerates whatsoever it touches, and penetrating into the water congeals it; this seems a precarious hypothesis, until we know on what experiments the doctrine depends. For my part, I have seen no great effects from the steams of nitre, more than of other saline bodies, in the production of cold; and the spirit of it, which is a liquor consisting of its volatile parts, appears not to the touch, to be actually colder than many other liquors, but even potentially hot. For whether or no the exhalations of nitre be able to congeal water into ice, I have formerly observ'd, that spirit of nitre, or *Aqua fortis*, will dissolve ice into water, nearly as soon as spirit of wine; a liquor generally allow'd to be potentially hot in a very high degree. *Gassendus*, indeed, asserts, that dissolv'd nitre mix'd with water freezes it, and that even in the summer; but I must freely profess, that altho' some other learned moderns teach the same thing, I, who am no stranger to nitrous experiments, have never been able to see any such effect: and 'tis somewhat strange, that chymists, who make frequent solutions of nitre, and often with less water than is sufficient to dissolve it all, so that its proportion to the water must have run thro' almost all possible degrees, shou'd never, by chance, have observ'd any such phenomenon.

But to come to our own experiments.

1. I took a pound of good salt-peter, and near three pounds of common water, (which was probably *Gassendus*'s proportion,) and put them into a large new pipkin, where they were kept constantly, and nimbly stirr'd, sometimes in a whirling motion, and sometimes in a more confus'd agitation, for almost an hour and a half, till we saw no likelihood of effecting any thing thereby; for we cou'd not perceive any atom of true ice produc'd, or so much as any freezing of the vapours on the out-side of the vessel: and, for this reason, we thought fit, at the same time, to try the experiment by another kind of agitation. Mixing, then two ounces of salt-peter with about six of water in a conveniently fiz'd vial, we successively and vehemently shook it to and fro, till we were almost tired; but neither by this way was there produced any ice within the glass, or the least congelation of the vapours on the out-side of it.

'Tis true, when so great a proportion of salt-peter began to dissolve in the pipkin, the water had a sensible increase of coldness, which afterwards seem'd to diminish, when once the nitre was dissolv'd; but we observ'd the water to be refrigerated, when, upon the dissolution of common-salt, multitudes of actually cold and solid corpuscles, came to be every way dispers'd thro' it, and the coldness produc'd

produc'd by the nitre, was very far short of the degree requisite to congelation; for to satisfy myself that my sense did not misinform me, I took a good seal'd weather-glass, about ten or twelve inches long, and immersing it into the cold mixture of nitre and water, I observ'd the tinged spirit of wine, in the stem, to descend considerably; and when the cold had wrought its effect, I remov'd the thermoscope into a vial fill'd with common water, about which was plac'd a mixture of beaten ice and salt; wherein the ball of the instrument being set, the spirit of wine hastily descended, two or three inches below where it stood when remov'd out of the nitrous solution. And for farther satisfaction, removing the thermoscope once again into that solution, the spirit of wine in the stem was hastily impell'd up, as if the bubble had been put into warm water. And once more, the glass being remov'd into the refrigerated water, the tinged liquor began to fall down hastily again, and soon sunk almost into the bubble; so that to avoid injuring the instrument, we took it out.

2. We found salt-petre wou'd readily dissolve ice, and, mixed therewith, freeze the vapours of the air to the outside of the single vial, wherein we made the experiment; which ice alone would not have done: and having plac'd some of the same nitre, grossly beaten in little heaps upon plates of ice, we manifestly found them to sink therein; which shews they dissolv'd it: and laying some upon a thick smooth piece of ice, we found it penetrate quite thro', whilst the surrounding part of the ice remain'd of a considerable thickness.

3. We put into a large single vial, almost full of water, as much rock-nitre, as, by the fire's side, wou'd dissolve therein, then expos'd them to the air of an extremely sharp night, and part of the following day; whereby the solution was frozen so hard, that having broken the glass, we cou'd hardly break the included mass. But at the bottom, there appear'd some liquor, with crytals of nitre well figured, that seem'd to have shot in it; which shew'd the water to have been sufficiently impregnated with the salt.

4. As to the spirituous parts of nitre, so far as we can judge of their temper by distillation, and by thermometers, they are not actually more cold than some other liquors, and appear rather potentially hot than cold; at least, they seem indispos'd to turn water into ice: for the spirit of nitre will readily, as we said before, convert ice into water.

From hence we may conclude, that there are bodies colder than salt-petre, as being able to freeze water, which that cannot congeal; and that nitre, which is said to be the efficient of ice, thaws and dissolves it; and consequently, in regard thereto, is rather hot than cold.

5. But to shew, that nitre does not always render water so cold as the common air, we suspended a sealed thermometer, for a considerable

PHYSICS. able time, in a very strong solution thereof; when coming afterwards to raise it, by the string whereto it hung, to avoid touching it with my hand, we found, tho' the day proved windy, the tinged liquor gradually descended $\frac{1}{4}$ inch; then placing it again in the same solution, the liquor again mounted to the same, or sometimes a greater height; for the experiment was often repeated.

6. If my opinion be then demanded, as to the refrigerating power of nitre; I answer, that I have not yet satisfied myself concerning it. I acknowledge, however, that among many other bodies which exhale from the terrestrial globe, nitrous corpuscles may be, generally, well qualified to cool the air; and, perhaps, there may be little saline bodies of kin to nitre, that, at certain times, plentifully float about in some parts of the atmosphere; but that this aerial salt, by some call'd volatile nitre, is true and perfect salt-peter, I cannot say: and that this salt alone shou'd be the *summum frigidum*, is more than I am convinc'd of; since there may be in the bowels of the earth many other bodies, whose effluvia have a power to refrigerate the air, equal to that of salt-peter. And as common salt, in artificial glaciations, is found to co-operate, as powerfully as salt-peter itself; and since it is undeniably diffus'd in vast quantities thro' the terrestrial globe; I see no reason why that kind of salt may not be rank'd among the universal efficient of cold. And hence, too, it seems probable, that it may often not be the emanations of one particular body, but a peculiar conjunction of two or more sorts, that produces an intense degree of cold. Thus we see that ice and snow have their coldness advanc'd, by the mixture of sea-salt, nitre, &c. Nay, I venture to assert, that actual cold may be manifestly promoted, and perhaps generated, by the addition of a body not actually cold. And I doubt, whether any saline or terrestrial exhalations, either single, or conjoin'd, be the adequate cause of cold; because there may be other ways of producing it, besides by the introduction of frigid corpuscles.

XXI.

Experiments
and observations
upon the
coldness and
temperature of
the air.

We have seen that the air is not the *primum frigidum*, yet, I cannot allow it to be neither cold nor hot, only as it is acted upon by external agents; for if we take cold, in the obvious acceptation of the word, for a quality relative to the senses of a man, whose organs are in a moderate temper as to cold, and heat; I am inclinable to think, that coldness may be attributed to the air, rather than heat, or a perfect neutrality both as to that and cold. To make a body cold, as to sense, it seems sufficient, that its minute particles shou'd less agitate the small parts of our organs of feeling, than they are usually agitated by the fluids of the body; and consequently, supposing the air destitute of calorific and frigorific atoms, it wou'd constitute a fluid, which,

which, either by the minuteness of its parts, or their want of vehement motion, may less affect the sense of feeling, than those fluids, and therefore appear actually cold. It is, by no means, necessary, that all fluids shou'd be as much agitated, as the vital humours of a human body; for in fish, and other animals, the blood and juices are always actually cold to our touch. And what reason is there, why the air shou'd not, in its natural state, be a cold fluid? For as to the grand argument, that air is easily heated by the action of the sun, or the fire, and as easily refrigerated by ice, snow, &c. and that heat and cold reign in it alternately every summer and winter; this only proves, that the air is susceptible of both these qualities; but does not shew, that one is more natural to it, than the other. Thus water may be easily depriv'd of its fluidity, by the application of snow and salt, and reduced to a fluid again by the sun or fire; and yet fluidity, not firmness, is allow'd to be the natural state of water. But, farther, it is manifest, that the heat of the air is adventitious, and communicated by the rays of the sun, or some other agent, naturally productive of heat in other bodies, as well as in that. 'Tis also evident, that upon the bare absence of the sun, or removal of other causes of heat, the air will, as it were of its own accord, become cold; whilst 'tis but an hypothesis, that swarms of frigorific atoms, diffus'd thro' the air, produce coldness therein, and not countenanc'd either by reason or experience. In some cases frigorific corpuscles may be allow'd of, yet, I see not why we shou'd have recourse to them, when a bare cessation of former motion, proceeding from manifest causes, may serve the turn; as it will for a sensible coldness in the air. And, upon this supposition, the air seems as justly to be term'd cold, as iron, marble, mercury, crystal, salt-peter, &c. which men unanimously agree to call so; to all which, the argument produc'd against the coldness of the air is applicable, except that the air, being a fluid, sooner receives and loses the impressions of heat and cold than they.

1. We fill'd a thermometer, to a convenient height, with well rectified spirit of wine, seal'd it hermetically, and inclos'd it in a glass receiver of a cylindrical form, about two inches in diameter, and a foot and a half high; and having cemented on the receiver, we left it for some hours, that it might perfectly cool. Then, drawing out the air, and watching it narrowly, we observ'd, that the liquor in the thermometer descended a very little upon the first extraction of any air, and somewhat less upon the second; but afterwards it did not sensibly sink: this subsidence of the liquor amounted, in the whole, to about the length of a barley corn; which we attributed to the stretching of the glass, by the spring of the included air, when the external was withdrawn; and accordingly, upon re-admitting the excluded air, the spirit in the thermometer reascended: and we afterwards drew out and let in the air, as before, with the like success.

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PHYSICS.

2. We applied a very hot handkerchief to the outside of the receiver, to try whether the included thermometer wou'd receive any impresson from it, when the air that had interpos'd was remov'd; but the liquor did not sensibly swell, either by this means, or by throwing thereon the concentrated rays of a candle, thro' a double convex glass. But the air being re-admitted into the receiver, the same handkerchief, heated afresh, and applied, made the spirit of wine sensibly ascend. But till the experiment be repeated in air of differing tem-
pers, no conclusion can hence be drawn as to its temperature.

3. Placing a small seal'd thermometer in a glass, broader at the top than the bottom, that was besmear'd on the inside with tallow, and furnish'd with water sufficient to cover the ball of the thermometer, we froze that water, and took notice where the tinged spirit of wine rested in the stem; after which, the ice being taken off from the ball in the open air of an exceeding frosty morning, the liquor immediately rose in the shank a little; as it happens, when a glass bubble, fill'd with warm water, is suddenly remov'd into cold; but presently after, the tinged liquor subsided a pretty way below its former mark: which shews, that the free air may communicate a more intense degree of cold, than ice itself.

4. The weather having continued very cold for some time, we plac'd an exact seal'd thermometer, that was made by the standard weather-glass at *Gresham College*, in a cellar, where we had observ'd beer not to freeze during a very sharp winter; and having looked upon it after two very frosty nights, the wind being at east, we found the tinged spirit of wine stood at two divisions, and about $\frac{1}{8}$ above the freezing mark; and on the following morning, which was very frosty, at the same height. Wherefore, having remov'd it into the free air, in the garden, it fell to the freezing mark; and, consequently, subsided above two inches beneath its station in the cellar. I hence observe, that the air in the cellar, notwithstanding the cold weather, was but very little warmer than that of my bed-chamber, in frosty weather; for the same thermometer being usually kept there, the spirit commonly stands at that time, about two inches above the freezing mark, in the morning before my fire is made; and in the summer-time, when the weather is very hot, it ascends to the eighth, ninth, and sometimes almost to the tenth mark.

5. On a night, that prov'd extraordinary cold, with frost, snow, and wind, the standard weather-glass was remov'd into the garden, and left there till morning, where the spirit appear'd to be subsided above two divisions below the freezing mark: so much greater was the cold of the air, than is absolutely necessary to congeal water; and yet the coldness of this very night, did not, by antiperistasis, so increase the heat of the cellar; but that a vial, containing about two or three ounces of chymical oil of aniseeds, which was left there till
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nine of the clock in the morning, remain'd unthaw'd: which argues, that the heat of the cellar was inferior to that of the external air in moderate seasons; since that oil is by the warmth of the air, both in the spring and autumn, preserv'd liquid; as this particular parcel of oil, in the same vial, was kept, by the moderate warmth of my chamber, several times this winter.

6. *December 29. 1665.* A little before ten of the clock in the morning, the weather having been frosty for near a fortnight, I took a seal'd thermometer out of my chamber-window, and having held it a while in the open air, in the court, and also wetted it with water, to reduce it the sooner to the coldness of the external air, I caus'd the ball of it to be held a pretty while in the reeking stream that came from the pump, and observ'd, that it made the tinged liquor considerably rise; the more so, the longer it was kept there, till it ascended to a great height; then carrying it up to my chamber, where there was a good fire, the spirit of wine began to subside again; thereby, shewing, that the air of my chamber was colder than the reeking water of the pump.

7. On *February 17.* After it had continued frosty for three or four days, about nine or ten of the clock in the morning, I caus'd the water of a considerably deep well to be pump'd, for a good while, upon the thermometer, after it had been kept for some time in the air; which water rais'd it, by degrees, about four or five eighths of an inch higher than the former. Then I carried the glass to a spring that used to smok in frosty weather, and having laid down the glass so as the ball might be cover'd with the water, just at the spring head, and let it rest there a good while, I found the spirit but very little rais'd; so that in all, it scarce mounted five eighths above the height it had been brought to in the preceding trial. Afterwards, in the same place, I brought the thermometer about noon to the north-side of the house, where the pump stood, and letting it rest against the wall in the open air for half an hour or more; I found, that tho' it had been that morning a small frost; and tho' the sun did not shine out, yet the air was about the same degree of warmth, the water seem'd to have at the spring-head in frosty weather, when there was snow upon the ground; and consequently the air was then much hotter than the water had been in the pump, where yet, in very cold weather, it usually smokes.

8. *February 19.* Being the third day of the continuance of a moderate frost, I held the seal'd thermometer under the pump, and having caus'd the water to run for a good while upon the ball of it, I found the tinged spirit rise as high as it had done many weeks before in the depth of winter, by the warmth of the water of the same pump.

9. On the next day, being the fourth day of the frost, the neighbouring spring, which had not smok'd during the precedent days, reek'd

PHYSICS.

reek'd this morning: and about noon, the weather being fair, and sun shining, the ball of the weather-glass was kept, for a competent time, cover'd with water, just at the head of the spring; when it appear'd to have risen higher now, by a quarter of an inch, than I cou'd make it do at the same spring-head several weeks before: but on this day, the water was a pretty deal warmer than the air; as appear'd by the subsiding of the spirit, when brought from the spring to my chamber; the ground being then cover'd with snow.

10. An ingenious man told me, he had often observ'd, in an exactly seal'd weather-glass, that the tinged spirit was higher at sometimes, when the weather prov'd frosty, than at others, when it did not; and that having kept his glass with the ball in water, which was afterwards frozen, and remain'd in the form of ice for several days, he warily broke the ice from about the ball, and removing it thence into the free air of the same room, he found the liquor to descend for above three inches. The ball of this glass I found to be of the magnitude of a middle sized crab, and the stem about two feet and a half long.

11. I formerly observ'd, that air included in tight strong vessels, is not sensibly condensed by cold; but that when the air is, in some part or other, expos'd to the pressure of the atmosphere, it wou'd, by a degree of cold, able to freeze water, be manifestly contracted; tho' how great this contraction may be, has not been hitherto determined: we have, indeed, attempted to do it in the following manner; from whence it will appear, that in our climate, the cold does not condense the air so much as is usually imagined.

And first, it may be proper to intimate, that among other ways we tried to measure the shrinking of the air, by sealing it up in glasses, furnish'd with long and very slender stems, that by breaking off the tips of them under water, after the included air was highly refrigerated, the water, by the pressure of the atmosphere upon it, might be impell'd into the cavity of the glass, and by its ascent therein, shew how much the internal air had been contracted by the cold; but this way we found too troublesome and difficult to practise with any thing of certainty; and never by this means, brought the air to lose above a 30th part of its natural dimensions.

12. Finding also some inconveniencies in using a bolt-head for this purpose, and any liquors capable of congelation, we at length employ'd a strong brine made with common salt, and once observ'd, that the cold of a frosty night, made the air shrink in the pipe of a glass-egg near five inches; and again we found, that the air possessing 2057 divisions, contracted by the cold of a sharp and frosty night, to 1965 of the same: which, with the utmost care, was the most we cou'd ever make the air lose of its natural dimensions, by any additional cold of the atmosphere; that is, a twenty second part, and a little more than a third.

13. We made the experiment, also, by the application of ice and salt, to the oval part of the vessel; which rais'd the liquor higher than in the former method, near four inches. And to determine the point more accurately, we found the air contracted by this means, from 1965, to which the cold of the external air had reduced it, into 1860 divisions; so that the effect of the ice and salt, added to that of the cold external air, did not contract the included air a tenth of its former space. And here 'tis remarkable, that there was no great difference betwixt the proportion, in which the cold condens'd air, and expanded water.

14. To proceed; cold may prodigiously hinder the warm effect of the sun upon the air, not only in the hottest part, but at several times of the day, even in the heat of summer.

An intelligent gentleman, who had several times sail'd in the frigid zone, assur'd me, that on the coast of *Greenland*, he had observ'd it to snow all midsummer night. An old sea-captain told me, that they are on the seas frequently pester'd with thick fogs extremely cold, which last, some of them, for ten or twelve hours, some for a whole day, and others two or three days together. He said farther, that lying at anchor in *Bell-sound*, on the coast of *Greenland*, near a mountainous rock, he with some others ascended to the top of it, which he judg'd half a mile perpendicular from the plain: here they found the weather clear, and the sky very serene; and it being then *June*, the sun shone vehemently hot upon them, whilst they saw a thick fog, like clouds, at the bottom of the hill; but when they came down, they found the fog as they left it, very dark and exceeding cold. And Mr. *Logan*, an *English* merchant, who winter'd at *Pecora*, a northern town of *Muscovy*, relates, that about the close of *August*, they had a strong frost, which lasted for four days. Capt. *Weymouth* says, that in *July*, tho' he was then far from the latitude of *Nova Zembla*, yet sailing in a thick fog, "they found their tackling so hard frozen, that it surpriz'd them; for it was then the middle of their summer." In the fifth voyage the *English* made to *Cherry* island, which lies betwixt seventy four and seventy five degrees of latitude, they observ'd, that the wind being at north-east, upon the twenty fourth of *July*, "it froze so hard, that the ice hung on their clothes;" and in their seventh voyage to the same island, they say, that "on the fourteenth of *July*, the wind being northerly, they had both snow and frost."

15. To give two or three instances of the sudden operations of the cold harboured in the air.

Dr. *Fletcher*, who went ambassador to *Russia*, tells us, that "when he there came out of a warm room into a cold, he sensibly drew his breath stiff, and even stifling with the cold: so powerfully and suddenly does the intensely refrigerated air work upon the organs of respiration."

PHYSICS.

“respiration. The chief physician of the *Russian* Emperor assured me, he has seen water, thrown up into the air, immediately fall down actually congealed into ice: and this relation Dr. *Fletcher* confirms, by declaring himself an eye-witness of the same thing. The same person farther declared, that being at the siege of *Smolensko* in *Russia*, he observed it to be so extremely cold in the fields, that his spittle would freeze in falling from his mouth to the ground; so that if he spit against a tree, for example, it would not stick there, but immediately fall to the foot of it.

16. Among the phenomena of cold relating to the air, I endeavoured to observe whether, upon the change of the weather, from warm or mild, to cold and frosty, there would appear any difference of the weight of the atmosphere, from its being plentifully furnished with a new stock of frigorific corpuscles, whereto several of the modern philosophers ascribe its coldness. But tho’ I, several times, compared an exact barometer, with a good sealed thermometer, furnished with pure spirit of wine, I could not find, that upon the coming on of clear and frosty weather, the atmosphere would very soon appear sensibly heavier than before: but I refer the matter to more frequent and continued observations than I yet have been able to make.

17. Another effect that the cold frequently has, especially in the northern countries, upon the atmosphere, is to render it more or less clear than usual; for in northern voyages the seamen frequently complain of thick and lasting fogs: on the contrary, it very often happens, that when the cold is very intense, the air grows much clearer than at other times; probably, because the cold, by condensing, precipitates the vapour that thickens the air; and by freezing the surface of the earth, keeps in the effluvia that would otherwise arise therein: it may also somewhat repress the vapours that would be afforded by the water it self; since some of our navigators observe, that when it is not cold enough to freeze the surface of the sea, it infrigidates it so, that the snow will lie undissolv’d thereon.

18. A *Swedish* ambassador, with whom I had the honour to be particularly acquainted, used to say, when he saw a clear frosty day, that it then look’d like a *Swedish* winter, where, when once the frosty weather is settled, the sky is usually, for a long time, very serene and pleasant: and here in *England*, we commonly observe, the sharpest frosty nights to be the clearest. And Capt. *James* tells us, in his journal, that in *Charlton* island, on the 30th and 31st of *January*, there appeared, in the beginning of the night, more stars in the firmament, by two thirds, than ever he had seen before. I could see “says he” the cloud in cancer full of small stars.

19. An ingenious gentleman, lately return’d out of *Poland*, inform’d me, that about the twenty first, twenty second and twenty third of *December* 1669, *Old-Style*, lying within three *Polish* miles of *Warsaw*, he every day beheld the sun accompanied with two parheliions, the one eastward, the other westward, almost in a direct line, and distant from it about eight

eight or ten diameters of the sun; and that they continued visible from near ten to twelve a clock: the weather being extream cold, the air was as clear as could possibly be imagined, both night and day, and when the sun shone, appeared full of glittering spangles or particles of ice.

20. To determine what effect the coldness of the air may have upon the refractions of the celestial bodies, seems a work of no small difficulty.

What I have here to say of it, is taken from the accounts of travellers. The *Dutch*, in *Nova Zembla*, who take great pains to shew, by several circumstances, that they were not mistaken in their account of time, declare, they saw the sun, after having lost sight of it for eleven weeks, fourteen days sooner than it ought to have appeared to them; which difference is usually ascribed to the great refraction of the gelid northern air. And as for that extremely cold country, where Captain *James* wintered, it appears, by his journal, that he there made several celestial and other observations, to give him some notice of this refraction, which he found very considerable, tho' nothing near so great as that which the *Dutch* observed in *Nova Zembla*. "On the twenty first of *January*" says he "I observed the latitude with great exactness, and found it $52^{\circ} 52'$; which difference proceeds from the great refraction:" for at his first arrival at *Charlton Island*, he took the latitude with two quadrants, and found it exactly 52° . And elsewhere he says, "by comparing my observations of the time of the stars coming to the meridian, we found the sun to rise twenty minutes too soon, and in the evening, to remain above the horizon twenty minutes too long; and all this by reason of the refraction." In another place he says, that "on *March 15th*, the moon rose in a very long oval along the horizon." And to cite only one passage more concerning refractions; "I often" says he "observed the difference betwixt clear weather and misty, refractious weather, in this manner. From a little hill near adjoining to our house, in the clearest weather, when the sun shone with all imaginable purity of air, we could not see a little island which bears from us *South South-East*, about four leagues; but if the weather were misty, we could see it from the lowest place."

21. To proceed; I observe, that the degrees of coldness, in the air of different climates, are nothing near so regularly proportionable to their respective distances from the pole, as is usually imagined.

In places equally distant, these from the north and those from the south pole, the latter are generally much colder than the former. What excessive cold reigns at *Moscow*, and the parts adjacent, during the winter, whereby many persons lose their noses, their toes, and some their lives, we have already observed; yet at *Edinburgh*, which is placed more northerly, by above a degree, and in the neighbouring places, the air is temperate, and the cold tolerable, the snow, it seems, seldom lies long on the ground after it is fallen. In an account of a

PHYSICS.

voyage made for northern discoveries, by Mr. *Pool*, in the year 1610, I find this passage, "I was certified that all the ponds and lakes were unfrozen, tho' fresh water; which makes me hope for a mild summer here, after so sharp a beginning; and my opinion is, that a passage may be soon obtained this way, by the pole, as any unknown way whatever; because the sun gives a great heat in this climate, and the ice made here near the 79°, is nothing near so huge as I have seen in 73°. To this agrees the testimony of the *Hollanders*, in their first voyage to *Nova Zembla*: "We have" say they "assuredly found that the only hindrance to our voyage, was the ice about *Nova Zembla* under 73, 74, 75 and 76 degrees, and not so much upon the sea between both the lands; whence it appears, that not the nearness of the north pole, but the ice that comes in and out of the *Tartarian* sea, caused us here to feel the greatest cold. It is true, that in the country lying under 80°, which we suppose to be *Greenland* both leaves and grass are to be seen, with such beasts as feed thereon; tho', on the contrary, in *Nova Zembla*, there grow neither leaves nor grass, nor are beasts there but such as feed on flesh, yet *Nova Zembla* lies 4, 5, and 6°. more southerly than that."

Josephus Acofta also tells us, that "in passing to the *Indies*, when he came to the equinoctial, in the month of *March*, he felt so great a cold, as obliged him to go into the sun-shine to warm himself. There is, indeed, says he "no region in the world more pleasant and temperate than under the equinoctial, tho' it be not in all places of an equal temperature; but the torrid zone, is, in some places, very temperate, as in *Quitto*, and on the plains of *Peru*; in others very cold, as at *Potosi*; and in others again very hot, as in *Ethiopia*, *Brasil*, and the *Moluccoes*. And again "says he "snow, hail, and frozen waters, are continually upon the tops of the mountains; and the cold is so severe, that it withers all the grass, and both men and beasts, which pass that way, are benumbed with cold: this happens in the torrid zone, and most commonly when the sun is in their zenith."

An old sea Captain, who has often sailed to *Greenland*, assured me, that he met with two masters of ships, the one from *Holland*, and the other from *Embsen*, who declared they had sailed to the latitude of 89 degrees, in quest of a proper place for whale-fishing; the journal of which voyage, they produced him; and the captain meeting the steers-man of one of the ships, discoursed with him, and saw his journal too; which agreed with what the others had declared. And afterwards one of the masters coming to *London*, he was there met accidentally by our captain, who brought him to some of the northern company, before whom he averred the foregoing relation, of whose truth the captain seem'd to be convinced. All the particulars that I could learn of this strange voyage, were, that tho' they met with vast regions of ice, towards the shores, yet when they found themselves near

near the pole, the ice was very open and free; so that if wood, water, and other provisions, had not begun to fail them, they might have made a passage, perhaps, as far as *Japan*; that from the north-east, there came a great rolling sea, which one of the masters, who had been at the bay of *Biscay*, compared to the *Spanish* sea; and that the cold there was not violent, but such as they could easily endure, and complained no more of, than they did in *Greenland*; that sailing from *Greenland* towards the pole, they found the compass to vary a point, after they had advanced some degrees northward; then again the variation of it was, for a great while inconsiderable, and soon after increased to two points, and, lastly, at 89 degrees of latitude, even to four points of the compass towards the east.

Mr. *Hudson*, in his second voyage, tells us, that "tho' at 71°, they were much peester'd with ice about the end of *June*, yet the weather was calm, clear and hot." And *Acosta* adds to this the account just delivered. "We see these differences not only on the land, but also on the sea; there are some seas where they feel great heat, as is reported of *Mazambicus* and *Ormus* in the east, and of the sea of *Panama* in the west; there are other seas in the same degree of latitude very cold, as that of *Peru*, where I felt it cold when I first sailed it in *March*, whilst the sun was directly over our heads."

Martinius, in his account of *Pekin*, tells us, that "altho' the pole be not there elevated above 42°. yet for four whole months from the middle of *November*, all the rivers are so frozen over, that the ice will safely bear coaches and the heaviest burdens. This congelation "he says" is, for the most part, made in one day; but the thawing of the ice requires many, and begins from the lower surface."

But not to multiply instances, we shall conclude with observing that *Charlton* Island, tho' it seems, by the effects, to be a colder region than about *Moscow*, and, perhaps, as cold as *Nova Zembla* it self; yet captain *James* assigns its latitude the same with that of *Cambridge*, viz. 51°. the air whereof is well known to be temperate: and 'tis remarkable, that this place was found uninhabitable by reason of the cold; yet, in Mr. *Hudson's* voyage, 'tis said, that "although they ran along near the shore, they found no great cold;" which made them think the place to be temperate, tho' they reckoned themselves to have then reached the 78th degree of latitude: and our later navigators inform us, that several parts of *Greenland* are well inhabited. An *English* sailor also assures us, that the true height of *Pustozera* in *Russia* is no less than 68 degrees and a half, and yet declares it to be a town of great trade. But in *Hudson's* voyage, I find what is still more strange, viz. that in the eighty first degree of latitude, beyond which they discovered land very far off, "they found it, during the whole day, clear weather, with little wind, and reasonably warm;" and beyond eighty

PHYSICS.

degrees, they not only found a stream or two of fresh water, but “ perceived it hot on the shore, and drank water to quench their thirst.”

’Tis also remarkable, that in *New-England*, where the winter is vastly colder than with us, lies 10 or 11° farther from the pole than we do.

22. The next observable I have to propose about the coldness of the air, is, that the degrees both of heat and cold therein, may be much greater in the same climate, and in the same place, at several seasons of the year, or even at different times of the same day, than is usually allowed.

For the proof hereof, we shall produce the testimonies of travellers. Dr. *Fletcher*, in his treatise of *Russia*, has this remarkable passage. “ The country, “ says he ” differs very much from it self, so that ’tis surprizing to see the great alteration caused therein by the winter and summer. All *Russia*, in the winter, lies under snow, which falls continually, and is sometimes a yard or two deep ; but more towards the north ; the rivers and other waters are all frozen up, to the depth of a yard or more, how swift or broad soever they be ; and this continues for five months, or from about the first of *November*, towards the end of *March*, when the snow begins to melt ; and yet, in the summer season, such a new face of the whole country appears, the woods are so fresh and sweet, the pasture and meadows so green and flourishing, there is such a variety of flowers and melody of birds, that a man cannot well travel in a more pleasant country. But as the winter exceeds in cold, so the summer inclines to too great heat, especially in the months of *June*, *July*, and *August* ; which are much warmer months with them, than with us in *England*.” The like particulars have been also lately affirmed by the learned *Olearius*. And an acquaintance of mine, who, after having liv’d in *Italy*, pass’d a summer in *Russia*, assured me, that he scarce ever eat better melons than at *Moscow*, which were there, he said, of a strange bulk ; and this gives credit to the relation of *Olearius*, who declares, he there met with melons which weighed forty pound. At *Pekin*, the capital city of *China*, which scarce exceeds the forty second degree of latitude, one would expect, that, as the summer is very warm, so the winter should be very mild ; as it is observed of *Spain*, *Italy*, *Greece*, &c. that have the same or a more northern latitude ; yet the learned *Martinus*, who lived many years in *China*, assures us, that usually for four months together, all the rivers are so hard frozen, that not only all ships are kept immoveable by the ice, but also horses, and the heaviest carriages, securely pass upon it ; and, what is very surprizing, he adds, that ’tis usually made in one day, tho’ many are required to dissolve it. *Prosper Alpinus* tells us, that at *Grand Cairo*, where he practised physick, tho’ distant fix degrees from the tropic of cancer, the air, which in summer is almost insupportably hot, is sometimes, in winter, very

very considerably cold. 'Tis related by *Purchas*, as communicated to him by an eye-witness, that in *Greenland*, it hath been, one day, so cold, that they could scarce handle the frozen sails; and another day so hot, that it melted the pitch off the ships; and that at mid-night, tobacco has been lighted by the sun's rays, with a glass. And lastly, Captain *James* gives us this account of the weather in *Charlton* island. "The sixteenth of *June*, "says he" was wondrous hot, with some thunder and lightning, so that our men went into the ponds, on shore, to cool themselves; tho' the water still remain'd very cold. There lately appeared several sorts of flies; as butter-flies, butchers-flies, horse-flies, and such an infinite number of blood-thirsty muskitoes, that we were more tormented with them, than ever we had been with the cold weather. These, I believe, lye dead in old rotten wood, during the winter, and revive again in summer: here are, likewise, infinite numbers of ants and frogs, in the ponds upon the land."

Thus we see what a difference there may be in the same place, betwixt the temperature of the air, in the winter and summer. We shall now add, what seems more strange, that there may be very great variations in the heat and coldness of the air, not only in the same place, but within the compass of the same day. *Prosper Alpinus* affords us an example hereof in *Egypt* it self, where one would expect a much more uniform degree of heat. "In the winter, "says he, "the nocturnal air is excessive cold, but presently grows warmer upon the rising of the sun, and by noon becomes hot; but towards night, it again changes for cold, from which irregularity proceed many diseases."

The learned *Olearius*, relating his passage over a branch of mount *Taurus*, takes notice, that, after the middle of *June*, the air of that hot region of *Persia*, obliged them to travel wholly by night; and yet the cold was then so great, that they were all benumm'd with it, and hardly able to alight from their horses; he adds, that the sudden change from an extream cold to the excessive heat they were again exposed to on the following day, cast, at once, fifteen of their company into a violent burning fever.

The same curious traveller mentions, that in another part of *Persia*, called *Faclu*, notwithstanding the heat of the region, towards the end of *March*, at which time they pass'd it; they, in one night, observed lightning and thunder, wind and rain, snow and ice.

And a learned physician, lately arrived from the *Indies*, assured me, that notwithstanding the violent heat in the day time there, he usually observed the nights to be so very cold, that he was persuaded some positively frigorific steams did then ascend out of the earth; which makes it expedient, says he, for the *English*, who live in the warmer parts of *America*, to imitate the natives in keeping fires under their hammocs.

The Czar's physician tells me by letter, "that the winter he spent at *Vologda*, which lies a few degrees to the north-east from *Moscow*, proved much

PHYSICS.

“ much less severe than usual ; for, as it happened, they had not three days of what they, there, call winter-weather.” He adds, that “ the cold, which is thought to be excessive there, hath been rare of late years ; for some *English*, who have liv’d upon the spot thirty years, declare, that, during their time, winters are become so mild, that the extreme cold, which used to freeze people on the road in several postures, hath not been felt as formerly.”

We will conclude with a remarkable instance taken from the journal of the *English*, who wintered at *Charlton* island. “ The season in this climate “ says Captain *James* ” is most unnatural ; for, in the day time, it “ will be insufferably hot in the sun, this being a sandy country ; yet, “ in the night, it will freeze again, an inch thick in the ponds : and “ all this towards the latter end of *June*.”

23. A third observable as to the coldness of the air, is, that in many places, its temperature seems not to depend so much upon the elevation of the pole, as upon the nature and circumstances of the winds that reign there.

’Tis a constant observation in these parts of the world, that northerly and north-easterly winds, at all times of the year, bring cold along with them ; and commonly, if it be winter, produce frost. And here in *England*, I have sometimes wondered at the power of the winds to bring not only sudden frosts, but sudden thaws ; when the frost was thought to have been settled. For, during one of the most considerable seasons of frost and snow, that I have taken notice of in this country, I found the wind, for many days, to be southerly ; unless it may be said that this southerly wind, was but the returning stream of the northern, which had blown for many days before ; and might, by some obstacles and agents, be made to wheel about or recoil, hither, before it had lost its refrigerating corpuscles. And Captain *James* observed, that the wind blowing southerly at *Charlton* island, in the month of *August*, the weather was snowy and foggy ; freezing their rigging, and making every thing so slippery, that they could scarce stand.

Prosper Alpinus attributes strange effects to the northerly wind in *Egypt*, as to cooling and refreshing the air, in spite of the violent heats that would, otherwise, be intolerable. And many in *Egypt*, he says, ascribe to the etesian winds, that almost miraculous ceasing of the plague at *Grand Cairo*.

Whence winds should have this power to change the constitution of the air, and, particularly, to bring cold along with them, is not easily determined. Other qualities, indeed, and even the heat observable in winds, may, generally, proceed from those of the places thro’ which they pass, as we have already observed : and it may be further confirm’d by what *Acosta*, himself, saw in some parts of the *Indies*, viz. “ that “ iron gates were so rusted and consumed by a peculiar wind, that, upon “ squeezing the metal between his fingers, it dissolv’d and crumbled “ like parched straw.” And this learned traveller, who seems to have taken

taken peculiar notice of the wind, affords us several examples, to confirm what we advance. "At a small distance," says he "many diversities may be seen in the same wind; for example, the east wind is, commonly very hot and troublesome in *Spain*, but in *Murria*, it is the most cold and healthful, because it passeth along the orchards and large champagnes which appear very fresh. But in *Carthage*, which is not far from thence, the same wind is troublesome and unwholesome: and the south wind," adds he, "is commonly rainy and boisterous, tho' in that city wholesome and pleasant." And in his description of *Peru*, he affirms, that the south and south-west winds are exceeding pleasant in that country.

But tho' many other qualities of winds may be deduced from the nature and condition of the places along which they pass; and tho' the heat, also, which *Proper Alpinus* attributes to the southerly winds in *Egypt*, may be, probably, ascribed to the heated exhalations, and vapours they bring from the southern and scorched regions they blow over; yet whence the great coldness of northern and easterly winds should proceed, may well seem strange to those who will not admit of corpuscles of cold. I shall, therefore, subjoin an experiment that I made, to give some light into this matter.

I caused a pretty large pair of ordinary bellows to be long kept in the room where we design'd to make our experiment, to receive the temperature of the air therein; then placing, upon a board, a flat-bottom'd weather-glass, furnished with a moveable drop of pendulous water, and blowing, at several times, with intermissions, upon the lower end of the glass, I found, that tho' the wind coming against my hand, felt manifestly cold, yet it did not cool the air included in the bubble, but rather a little warm'd it; as appear'd by a small sensible ascent of the pendulous drop, after the lower part of the glass was blown: upon which seem'd to proceed from some small alteration towards warmth, that the air received by its short stay in the bellows; for if by closely covering the clack, the air came into the bellows, wholly thro' the nose thereof, whilst held very near the bubble of the glass, that stream of wind coming from a part of the window where the air was a little cooler than that which was before blown out of the bellows, would not, as the other, make the pendulous drop rise, but rather the contrary.

We then proceeded to shew, by experiment, that tho' a wind were only a stream of air, yet in its passage it might acquire a considerable coldness, distinct from what it has by virtue of its motion, tho' upon that score, we see the air mov'd by a fan, or a pair of bellows may feel cold to our touch. Having inverted a ridge-tile, and half fill'd its cavity with a mixture of ice and salt, we plac'd the iron pipe of the bellows upon that mixture, and cover'd it with more of the same, that so the pipe being surrounded thereby, the air contain'd

PHYSICS.

tain'd in it might be highly refrigerated; then blowing the bellows against my hand, the blast felt much colder, than what came out of the same bellows before the refrigerating mixture was applied. But for fear my sense of feeling might deceive me, I caus'd a thermometer, made after the common manner, but with a more slender pipe, to be so plac'd, that the nose of the bellows lay level with the bubble of the glass; and then blowing the refrigerated air of the bellows upon the globular part of the thermometer, the water in the cylindrical part and shank, manifestly ascended, as is usual upon the refrigeration of the included air; and as this ascent of the liquor continued during three or four blasts of the bellows, so upon the cessation of the artificial wind, it again subsided, by degrees, till by fresh blasts it was again impelled up. Lastly, having repeated this experiment, we drew back the nose of the bellows, that the air to be now blown out, might pass along the cavity forsaken by the iron pipe; when, the wind was manifestly more cold than before, and had a greater effect upon the thermometer, against which 'twas blown. And to satisfy myself, that it was not the bare wind, whose operation upon the air included the ball of the weather-glass caus'd the liquor to ascend, I mark'd the height it stood at, after we had, for a pretty while, blown upon it; and then, without removing the bellows, put ice and salt about the iron pipe of them; by which means the air afterwards blown thro' that pipe, was so cool'd in its passage, as to make the fluid very manifestly ascend, even in a weather-glass, where quicksilver was us'd instead of water, or spirit of wine. And lest the nearness of the frigorific mixture shou'd be suspected to have caus'd this contraction of the included air, we sometimes purposely intermitted the blasts of the bellows, without removing the weather-glass; and tho' notwithstanding that vicinity, the liquor wou'd begin a little to subside, yet whenever the cold corpuscles of the highly refrigerated air, were, by the playing of the bellows, brought anew, to touch in swarms, the globular part of the instrument, the mercury wou'd manifestly rise. I find, however, that the season of the year, and some other circumstances, may considerably vary the experiment. For tho' I have here faithfully recited the phenomena of it, yet coming some months after, and in different weather, to repeat it, I was surpriz'd at the success. For, blowing upon the ball of the seal'd weather-glass, I found, that if I continued to do this long and briskly, the highly rectified spirit of wine wou'd sometimes manifestly subside.

However, this experiment duly prosecuted, may possibly afford still farther light.

But I will not here pretend to determine, whether all cold winds must be necessarily made cold, by frigorific corpuscles, properly so call'd; for I have sometimes suspected, that winds may be cold only by consisting of, or driving before them, those higher parts of the air, that,
by

by reason of the languid reflection of the sun's rays in that upper region, are generally very cold; for it may be observ'd, that rains often greatly and suddenly refrigerate the lower air, when no winds but what the rain and clouds occasion, attend them; as if they brought cold air along with them from that upper region; which both *Acosta*, and one who has visited far higher mountains than the *Alps*, affirm to be, in some places, exceedingly cold in hot climates, and hot seasons of the year. But to leave this conjecture, Mr. *Wood* informs us, that "tho' in *England*, most of the cold winds and weather proceeds "from the sea; and tho' those situations are counted most unwholsome "that are near the coast; it is otherwise in *New-England*." And having added as his reason, that "the north-east wind coming from the sea, "produces warm weather, melting the snow, and thawing the grounds;" "he subjoins" only the north-west wind passing over the land, is the "cause of extreme cold weather, being always accompanied with deep "snows, bitter frosts, &c." To which we shall add this passage from Capt. *James's* voyage. "The winds since we came hither, have been "very variable and inconstant, and till within this fortnight, the "southerly wind was coldest. The reason, I conceive to be, because "it blow'd from the main-land, which was all cover'd with snow; and "that the north winds came out of the great bay, which hitherto "was open." And lastly, I have been assur'd, that in *Greenland* itself, the north-east winds were colder than any other; which my relator ascrib'd, in part, to the situation of the country; those winds blowing over vast tracts of ice without any sea, to mitigate the cold they communicate.

XXII.

I come now to consider those effects of cold, that are not familiar, but seem to have in them something of wonderful. Strange effects of cold.

As to the power of cold, either to contract the sphere of activity of fire, or to hinder its usual effects, the chief examples I have met with are recorded, by the *Dutch*, to have happen'd in *Nova Zembla*, and by Capt. *James*, when he winter'd in *Charleton* island. These *Hollanders* speak thus. "On the twentieth it prov'd fair and still weather, the wind easterly; but it was so cold, that when we had wash'd "and wrung our sheets, they presently froze so stiff, that altho' we "laid them before a great fire, the side that was expos'd thereto "was thaw'd, but the other remain'd hard frozen." And again, "we "were in great fear, that if the extremity of the cold increas'd, we "shou'd all die there; for what fire soever we made, it wou'd not "warm us." Tho' Capt. *James* winter'd in a country many degrees more remote from the pole than *Nova Zembla*, yet he gives us this account of the power of the cold to oppose the action of fire. "The "cook's tubs wherein he water'd his meat, standing about a yard from

PHYSICS.

“ the fire, and which he all day long ply’d with snow-water, were in the night season firmly frozen to the bottom; and therefore he was oblig’d to water his meat in a brass kettle, close adjoining to the fire: and I have often found the side next the fire very warm, whilst the other remain’d frozen an inch thick.”

This relation, compar’d with those of the *Hollanders*, makes me the less wonder it shou’d be related to *Marcus Polus*, that there is a certain plain in *Tartary*, situated between some of the highest mountains in the world, “ where if fire be kindled, it burns not so bright, nor proves so effectual to boil any thing, as in other places.”

These relations of travellers, tho’ to us who live in *England*, they cannot but seem strange, yet I dare not reject them as incredible; because ice and snow having been water before their congelation, must, in probability, owe their coldness to that which reign’d in the air; so that if in any place, nature has either so plentifully stock’d the air itself with frigorific corpuscles, or upon any other account rendred it as cold as ice, and snow are amongst us; I know not why in more northern climates, where, perhaps, some saline exhalations arise from the earth and sea, a coldness may not be diffus’d thro’ the air, superior to that which, by small quantities of ice and salt, is at a small distance producible here; yet this is so intense, that by pouring some water on a board, and placing a convenient vessel thereon, we may with beaten ice, or snow and salt, and a little water, nimbly stirr’d together in that vessel, make the mixture freeze the external water quite thro’ it, to an excessive degree; and that too just by the fire.

How greatly the air is affected by cold, we have seen already, by the freezing of spittle, or water, barely in falling thro’ it: and to give two or three remarkable instances of its effects upon fluids, ’tis said, that on the 27th of *September*, it froze so hard, that as the *Dutch* in *Nova Zembla*, put nails into their mouths, to be in a readiness for driving, ice wou’d hang thereon; and when they took them out again the blood wou’d follow. And this is scarce more strange than what is affirm’d by *Dr. Fletcher*, who speaking of *Muscovy* says, “ if you there in the winter hold a metalline vessel in your hands in the open air, they will stick fast together, so that the skin will come off when you part them.” Nay, in *Russia*, and some other cold countries, if a man be abroad in the winter air with a cane, furnish’d with a metalline head, and the tip of the tongue be applied to the metal, they will stick, and be as it were glew’d together; so that they cannot be sever’d without great pain, and sometimes not without leaving the skin of the tongue behind. And this has been affirm’d to me by eye-witnesses of unquestionable credit. An ingenious physician, also, affirm’d to me upon trial, that the pummel of a sword, expos’d to the winter air in *Moscow*, wou’d stick to the tongue that touches it, and fetch off the skin, if forcibly and suddenly pull’d away.

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The reason of so odd a phenomenon, as far as I can conjecture, may be the great and sudden loss of agitation in the *Saliva*, and part of the tongue. Thus, if an ivory ball meet, in a direct line, with another of equal bigness, moving upon a billiard-table, 'twill communicate to it a part of its own motion, and retain the remainder; but if the latter were at rest, the ball impell'd against it, will communicate almost all its motion thereto, and lose as much itself; as appears by its remaining quiescent in the place of the other. In like manner, the metalline head of the stick, by the intenseness of the cold, may have its parts so depriv'd of motion, that when those of the *Saliva* and tongue have communicated as much of their agitation as they can, there will not remain among those three bodies a sufficient degree of motion to keep the spittle fluid; which therefore being turn'd into ice, will stick to both the consistent bodies, the tongue and the metal, and by this means fasten them together. In confirmation of this conjecture, I might add, there are some other phenomena explicable by the help of it. For instance, in very frosty mornings, the ice which sticks to glass-windows, and often appears in the form of trees, or other odd figures, is vulgarly accounted for by supposing the cold produced them on the out-side of the glass, which, some fancy the vapours of the warm room penetrate. But 'tis plain, that this ice is formed within the room, as I have often observ'd, either by the thawing or scraping it off; so that it appears to be made of vapours floating in the air and chancing to pass along the glass of the windows; which by the cold of the external air in frosty weather, losing the natural agitation of its parts, these transferring so much of their motion to the glass, retain not enough to keep them fluid; the consequence whereof is, they are turned into ice, which, in very cold countries, will be far thicker than in *England*; and accordingly, an acquaintance of mine assured me, he observ'd the ice on the in-side of the windows of some stows in *Russia*, to be near an inch thick. And tho' *Macrobius* and other learned men, disallow salt-water to be congealable, yet the *Dutch* relate, that at *Nova Zembla*, even in the midst of *September*, "it was froze two inches thick."

The effects of extreme cold upon the common earth, are very remarkable. *Olearius* relates, that in the year 1634, the cold was so bitter at *Moscow*, that in the great market-place he saw a cleft many yards long, and a foot broad, occasion'd by it: and the like has been confirm'd to me, by the *Czar's* chief physician.

'Tis somewhat strange, that both the violent heat of summer, and the extreme cold of winter, shou'd produce the like effects in the ground; but not having yet made the proper experiments, to shew from whence this phenomenon proceeds, I do not pretend to determine the cause thereof.

PHYSICS.

The *Dutch*, in their third voyage to *Nova Zembla*, tell us, that “when they had built a wooden house, and were going to shut themselves up therein, for the winter, they made a great fire on the outside, to thaw the ground, that they might place wood about the house to make it the closer; but it was all lost labour: for the earth “was so hard, and frozen so deep, that they cou’d not thaw it.” *Martinius Cromerus*, in his *Polonia*, records, that “cold is sometimes so “violent there, that trees wither at the roots, and water pour’d from “on high, turns to ice before it reaches to the ground; that the “lakes, marshes and rivers, are so frozen for two or three months “in the winter, and sometimes for five or six, that horses and loaded carriages may freely and securely pass over them. And I myself,” says he, “have on the last day of *March*, pass’d over the *Weissel* in *Masovia*, upon the firm ice, with a coach and four horses, and “a retinue of horsemen.”

After having seen some strange effects of cold upon the several elements, we proceed to take notice of its power upon compounded bodies. But as we have already deliver’d its operation upon beer, ale, vinegar, oil, wine, &c. as also upon wood, bricks, stone, vessels of glass, earth, pewter, iron and brass, with many strange effects of it upon other inanimate bodies; we shall here produce no more instances of that kind, but proceed to observe the effects of the same quality upon animals. We may, however, first intimate in general, that tho’ many plants are preserv’d by a moderate cold, yet it has been found, that most garden plants are destroy’d by excessive degrees thereof. Capt. *James* speaking of the greatest degree of cold, viz. that which he and his company felt in the woods of *Charleton* island, says, “it was so extreme “as to be intolerable; no clothes were proof against it, no motion “cou’d resist it. It wou’d freeze the hair of our eye-lids, so that “we cou’d not see; and I verily believe, it wou’d have stifled a man “in a few hours time.”

Olearius giving an account of the air of *Muscovy*, and especially of the capital city thereof, tells us, “the cold is there so violent, that “no furs can prevent it; but that sometimes men’s noses and ears, “feet and hands, will be frozen and fall off;” he adds, “that in the “year 1634, when he was there, they cou’d not go fifty paces without being benumm’d with cold, and endangering the loss of some “of their limbs.”

Dr. *Fletcher* speaking of the cold, that sometimes happens in *Russia*, affirms, that “not only travellers, but people in the very markets of “their towns, are kill’d by it; so that many drop down dead in the “streets, and travellers are brought into the towns sitting dead and “stiff in their sleds; and abundance lose their noses, the tips of their “ears, and the balls of their cheeks, their toes, feet, &c. When the “winter is very hard, the bears and wolves often issue by droves out

“ of

“ of the woods, driven by hunger, and enter the villages, tearing and
“ ravageing all they can find; so that the inhabitants are oblig’d to
“ flee for their lives.” PHYSICS.

To descend now to the more particular phenomena of cold in the human body.

An old sea-captain told me, that when he was in *Greenland*, his appetite grew so great, that he cou’d eat more in one day, than in a week or ten days here; and that accordingly, both he and others found themselves stronger there, than in *England*, and more inclin’d to venery.

’Tis related of the *Hollanders* in *Nova Zembla*, that if they remain’d long in the open air, there arose blisters upon their faces and ears: and Capt. *James* says, “ the cold in the woods wou’d freeze our faces, “ or any part of our flesh that was bare.”

The *Dutch* speaking of the pains they took to dig away the snow, that cover’d the house, and choak’d up their door, say, “ they were “ forc’d to use great expedition, for they cou’d not long endure “ the extreme cold air, tho’ they wore foxes skins about their heads, “ and double apparel upon their backs.” Capt. *James* farther relates, that in *Charlton* island he was oblig’d to cut the hair of his head short, and shave away all that of his face, because the icicles wou’d otherwise fasten thereto, and make it intolerable. And he again says, that he and his companions having once been parted for a little while into two companies, “ they all had their faces, hair and clothes, so frozen over, that they cou’d not know each other by their habits, nor “ even by their voices.” And the same author gives this account of the death of the gunner of his ship, whom he calls a strong-hearted man, who died before the end of *November*. “ He had, “ says the Capt. “ a close boarded cabin in the gun-room, which was close indeed, and “ as many clothes on him as was convenient, and a pan with coals “ of fire continually in his cabin; for all which warmth, his plaister “ wou’d freeze at his wound, and the bottle of sack at his head.”

“ The 11th of *December*, “ says the writer of the *Dutch* voyage to “ *Nova Zembla*,” was fair weather, the air clear, but very cold, for “ our shoes froze as hard as horns upon our feet, and within side they “ were white; so that we were forced to make great pattens, the upper part of sheep-skins, which we put on over three or four pair of “ socks, and so went in them to keep our feet warm; but the clothes “ upon our backs were all over white with frost.” And says Capt. *James*, “ our bed-clothes wou’d be cover’d with hoar-frost, which lay not “ far from the fire.”

We might add from *Gerat de Veer*, that “ on the 26th of *December*, it “ was foul weather, the wind at north-west, when it prov’d so cold “ we cou’d not warm ourselves, tho’ we us’d all possible means, great “ fires, store of clothes, hot stones and billets applied upon our feet,
“ and

PHYSICS.

“ and upon our bodies, as we lay in our cabins; but notwithstanding all this, our cabins were frozen in the morning.

A knowing and very credible person has related to me of the cold of *Russia*, where he travell'd, particulars almost as strange as those I have mention'd from books: and a very learn'd traveller assures me, he met with a strange operation of the inclemency of the air, upon multitudes of men at once, recorded in an approv'd history; viz. that, about the year 1498, an army of the *Turks* having made an incursion into *Poland*, were upon their return, surprized with such an extremity of cold and of snow in *November*, that out of the whole army, which consisted of 70000 men, 40000 perish'd upon the spot.

Amongst the many relations I have met with, of the fatal effects of cold in northern countries, I am surpriz'd, I cou'd not find any account of the change made in the internal parts of the bodies kill'd by it. But meeting with a description of a *Polish* province, call'd *Ukraine*, of the same latitude with *Normandy*, and often subject to excessive cold, I find the author gives an account, not indeed of what I sought for in him, but of two differing effects of cold upon the bodies of men. The first is, that sometimes, when the natural heat proves strong enough to protect the toes, cheeks, ears, and other parts, that are either more remote from the heart, or more tender, from a sudden mortification; yet unless nature be assisted either by good precautions or remedies, she cannot hinder the cold from producing cancers in these parts, as painful as those which are caus'd by a scalding and malignant humour; which shew'd me, says our author, that cold has as great a power to destroy things, as fire to consume them. He adds, that the beginning of these cancerous sores is so small, that what produces the pain, scarce equals the bigness of a pea; and yet in few days or hours it spreads so, as to destroy the whole part it invades: and this he confirms by the example of two persons of his acquaintance, who thus immediately lost the characteristics of their sex. As to those who are kill'd with cold, our author says, they perish differently. For some, not being sufficiently fortified against the cold by their own internal heat, nor competently arm'd against it by furs, inunctions, and other external means; after having their hands and feet first seized, till they grow past feeling it, the rest of their bodies is so invaded, that they are taken with a drowsiness, that gives them an extreme propensity to sleep, which if indulg'd, they awake no more, but die insensibly. And from this kind of death, our author adds, he was several times snatch'd by his servants, who were more accustomed to the cold than he, and seasonably forc'd to awake out of those drowsinesses, which they knew to be dangerous. And indeed, that death by cold is sometimes indolent, the relations of some intelligent acquaintance of mine, who have been in exceeding cold countries, confirm.

But

But the other way whereby cold destroys a man, is the most remarkable. He tells us, that sometimes the cold seizes the reins, and all about the waist, especially horsemen, underneath the armour of the back and breast; and strikes into those parts so forcibly, that it freezes the *abdomen* and *viscera*; so that tho' they have keen appetites, they cannot digest or retain the lightest aliment, but presently reject it by vomit, with unspeakable gripings and pains; and so continually complaining of their condition, and sometimes crying out, as if their bowels were tearing out, they end their miserable lives almost in madness and despair. Having seen some of these departed wretches open'd, he says, they found the greatest part of their *viscera* black, burn'd up, and as it were glew'd together; whence he thinks it probable, that as their bowels came to be gangrenated, they were forc'd to those complaints and exclamations; and we may add, that, probably, upon the same cause depended those continual vomitings of what they eat and drank; the gangrene of the guts hindering the passage of the excrements downwards, as it often happens in the true *Iliaca Passio*; and the peristaltic, or the usual motion of the guts being inverted, as it also frequently happens in the same disease. Anatomists and physicians, no doubt, will think this account very imperfect; but 'tis the best, and, indeed, the only one, I have hitherto met with of this distemper; tho' I cou'd wish it had been much more full and particular, and that he had also open'd those animals, and especially their brains, which he mentions to have been kill'd suddenly, and without pain, by cold. For, such informations, (the want whereof, as far as our climate wou'd permit, I have had thoughts of supplying by experiments upon other animals,) wou'd perhaps satisfy me in a conjecture, countenanc'd by several trials upon vegetables and animals after death, as to the cause of mortifications produced by excessive cold.

What effects may be produc'd by violent cold upon other animals, I scarce find mention'd by any writers I have met with. The author, indeed, lately quoted M. de *Beauplan*, tells us, in general, that the cold in *Ukrain* is sometimes so great, as to be scarce supportable by horses, and some other cattle. He also mentions a familiar four-footed animal, call'd *Bohack*, said to be peculiar to those parts, that hides itself under ground in winter. A *Polish* nobleman told me, that when he was in that province, he had one of them presented him as a rarity, which some of the *Poles*, chancing to dig in a retired place, were surpriz'd to find: and tho' this creature was frozen so stiff, that they thought it to be stark dead; yet when they came to flea it for its skin, it was awaken'd by pain, and recover'd itself.

That some other animals may be frozen till they are stiff, and yet recover, we shall see hereafter. 'Tis a tradition among those who travel into northern climates, that both birds and wild beasts, are in icy and snowy countries, ordinarily turn'd white, in the winter, by the coldness of those parts. This account I dare neither admit as true

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PHYSICS.

universally, nor reject as utterly false. For, not now to enquire into, the cause of this whiteness, I find, by the voyages that I have perused, that sailors often mention their meeting with numbers of white bears and foxes in *Nova Zembla*, and other very northern regions; and also, sometimes, with herds of white deer: and in the *Alps*, which are always covered with snow, credible authors mention, there having seen white partridges. And I remember, when I was in *Savoy*, and the countries adjoining thereto, where the tops of the mountains are almost perpetually covered with snow, frequent mention was made to me of a certain white kind of pheasants to be met with in the upper parts of the mountains, which were accounted very delicious. But on the other side, the same sailors, treating even of the coldest climates, seem to distinguish the white bears from others of those parts. And 'tis from very northern countries, that we usually receive dark coloured furs, and the skins of black foxes, as well as white ones. But as for the herds of white deer, their colour may proceed from seminal impressions; since here, in *England*, I have seen white ones. And tho' *Greenland* be some degrees nearer the pole than *Nova Zembla*, yet I have seen a live deer brought from thence, whose skin was not white, but rather of a kind of dun; and his coat might well have pass'd for a fur. Yet these two particulars seem to favour the efficacy of cold; the one, that in several cold countries, as particularly in *Greenland* and *Livonia*, even modern describers of them affirm hares will turn white in winter, and return to their native grey colour in summer; the other, that tho' *Charleton* island differ not one degree in latitude from *London*, yet Captain *James* takes notice of foxes there, that were pied, black and white; and also of white partridges.

Two *Swedish* ambassadors assured me, that in *Muscovy*, and some other northern countries, the hares are of the same colour with ours in summer, but snow white in winter; and that they begin to change colour in autumn, and to recover it in the spring. The elder of them, Monsieur *Coyet*, assured me, he had himself observed the thing; and the same was, likewise, affirmed by the *Swedish* resident then present; who farther added, that on the borders of *Muscovy*, he had seen numbers of milk white partridges in winter; and they all three agreed, that squirrels, which, in summer, are of the usual colour with ours, do, in the winter, turn grey, and recover their brown colour the following summer. They were pleased, also, to send me word by an ingenious gentleman, son to Monsieur *Coyet*, that on one side of the river *Duna*, which divides *Livonia* and *Muscovy*, the hares are of the ordinary colour, but on the other side white; so that when the hunts-men meet with any white ones, on that side the river, supposed peculiar to the other, they call them deserters.

An old sea-captain told me, that the white bears in or about *Greenland*, notwithstanding the coldness of the climate, have an excellent nose; and that sometimes, when the fisher-men had dismissed the carcass of

a whale, and left it floating on the waves, three or four leagues from the shore, whence it could not be seen, these animals would stand as near the water as they could, and raising themselves on their hind-legs, loudly snuff in the air, and with the two paws of their fore-legs, as with fans, drive it as it were against their snouts; and when they were (as my relator supposed) satisfied, whence the odour came, they would cast themselves into the sea, and swim directly towards the whale, as my relator and others observe, who had sometimes the curiosity to row, at a distance, after them; to see whether their noses would serve them for guides, when their eyes could not. He saw no other bears in those parts but white ones.

An inquisitive person told me, that having resided for some time in *Prussia*, he had, more than once or twice, in different places, observed, as others in his company also did, that the fisher-men, in breaking the ice of ponds which had been long frozen, and taking out thence considerable masses of it, several times found many swallows in them, so inclosed in the ice, as not to be got out but by breaking or thawing it. He farther said, that when these lumps of ice came to be thaw'd in the stoves, the swallows, which lay seemingly dead before, would revive, and perhaps fly about the room, but did not long survive their recovery out of their insensible state; some dying again in few hours, others the next day, or perhaps on the third; but few or none, that he observed, lived beyond the fourth or fifth. This, as my relator judg'd, happened thro' their want of appetite; but, I believe, it proceeded principally from their want of flies and proper animals to feed on, which they could not obtain in the winter.

XXIII.

Since many ingenious men assert, that water is turned into ice by the introduction of frigorific corpuscles, we thought fit to try whether a liquor, by its increase of weight when frozen, would betray them. And the first experiments we made to discover this were with eggs.

Experiments upon the weight of bodies, frozen and unfrozen.

1. We placed an exact balance in a frame, and into one scale thereof put two eggs, and counterpoised them with brass weights, then suffered all thus to continue, during a very sharp night in a turret; and coming the next morning to view them, we found the eggs grown lighter by very near four grains: we afterwards repeated this experiment twice or thrice; but having been diverted from registering the events, I dare only say, that some of the circumstances seem'd very odd and uncertain; and that I desisted from prosecuting it, because an increase of weight in eggs, thus exposed, was hardly to be hoped for, since part of the more subtile and spirituous corpuscles they contain, continually get away thro' the pores of the skin and shell: which seems to be the reason why eggs long kept, have usually within the shell, a considerable cavity; so that tho' the frigorific atoms should, by their ingress, here add a small weight, yet that would not, unless perhaps in the very juncture when the congelation is first actually made, be taken notice of.

PHYSICS.

2. And for farther satisfaction in this matter, we carefully counterpoised four hen-eggs in a good pair of scales suspended at a frame, and suffering them to continue for a pretty while, we observed, that tho' it were winter, and tho' the room made choice of was destitute of a chimney, yet that scale wherein the eggs lay, grew manifestly lighter, so that it was requisite, from time to time, to take a grain out of the opposite scale, to reduce the balance to an equilibrium; and by this means, we found the eggs, after some time, to have lost eight grains of their former weight; but how much more they would lose, we could not stay to discover.

3. I endeavoured, also, to satisfy my self, whether eggs, when once actually frozen, and kept in a pair of nice scales fastened to a frame, in some quiet place that was well fenced from the sun, would, by the cold of the air, in freezing weather, continue for any considerable time without a sensible diminution of their weight; but an unexpected thaw hindered us from seeing the success of what we designed of this nature, both as to eggs and some other bodies. But if the experiment were very carefully made upon a competent variety of them, especially upon camphire and some other very exhalable bodies; it might possibly assist us to guess what interest the cold has in the suppression, or exhalation of their effluvia.

4. But to return, a single vial of water sealed up, wiped dry, and weighing four ounces four drams and a half when froze by ice and salt, lost by being thaw'd somewhat more than a grain.

5. We took a thin vial furnished with a long neck, which at the flame of a lamp, was drawn gradually slender, so that being very narrow at the top, it might the more readily be sealed; this we filled with water, allowing room for its expanding upon glaciation, and placed it in a mixture of snow and salt; when the glass appeared nearly full of ice, it was taken out immediately, seal'd hermetically, and weigh'd in a pair of very good scales; whereby we found the whole amount to six ounces and half a grain, tho' some of the ice began to thaw in the operation: the vial being thus removed, and suffered to stand alone for two or three hours, the ice was vanished; when we again put the containing glass, in the same scales, and found that it weighed rather a little more than before; but this not amounting to half a grain, it might well be attributed to some difference in the weights and grains themselves, or to some unheeded moisture that might adhere to the vial.

6. We placed another very thin vial of water, sealed as the former, that weighed four ounces, two drams, forty one grains, in a mixture of snow and salt; thereby freezing it warily, to prevent its breaking; then we removed it into the same scales, and found it to weigh either just as before, or, if there were any difference, to have lost a quarter of a grain. Being suffered to thaw, we placed it in the scale again, and

and found its weight the same when frozen, tho' the weights were numerically the same, and about $\frac{1}{3}$ of a grain would turn the scales. I was careful this last time to wipe the outside of the glass with a linen cloth, because I had observ'd, if ice be hastily thaw'd, it will there produce a dew.

Captain *James* gives us a particular in his voyage, which, if it had been circumstantially set down, might prove of moment in regard to the weight of bodies frozen and unfrozen. "We hoisted our beer and cyder," says he, "and made a raft of them, fastening them to our shore-anchor; they both sunk presently to the ground; which was nothing strange to us, because any wood or pipe-staves, that had lain under the ice all winter, would sink down as soon as ever they were heav'd over board."

7. I was, also, desirous to see whether any difference, as to weight, would be produced by freezing and thawing iron, stone, wood, or the like solid and permanent bodies, which I intended to have exactly weigh'd before and after they were exposed to the air in frosty weather; and again, after the frost was gone; and this against counterpoises, not exposed to so great a degree of cold. And tho' we were prevented from bringing the matter to such an issue as we desired; yet this kind of experiments seems not irrational; since its highly probable, that even stones and metals suffer a change of texture by the action of some degrees of cold. And I remember to have made several experiments as to the weight of some metals and stones, both before and after they had been long exposed to a more vehement cold than would have sufficed to turn water into ice, and also after they had been left exposed to a warm air; tho' the paper in which we registred the events of these trials having been mislaid, I dare not charge my memory with the particulars: but if I mistake not, one or two stones increased their weight, by being buried in our frigorific mixture; which may be imputed to some particles of the ice resolved into water, by the salt imbibed into the pores thereof. For having procured an experiment to be made by an ingenious person, upon a stone hard enough to bear a good polish; he inform'd me, that the stone, by being kept a while in water, tho' it was afterward wiped dry, discovered a manifest increase of weight. And in confirmation of my conjecture, I might add, that from a sort of stones, of a texture close enough to bear a polish, I obtained, by distillation, a considerable quantity of an almost insipid liquor, which I suspected to be, chiefly, water soaked into the stone. But such trials as these, with others of the like kind, we leave to be farther prosecuted. However, those we made in sealed vials, were managed with accuracy; and some of the rest were designed to satisfy others rather than our selves; for should an additional weight be found in frozen bodies, yet how do we hence know that the atoms of cold are either heavy or light, any more than the effluvia of magnetic and electrical bodies?

PHYSICS.

8. The experiments here delivered, may, perhaps, keep men from being misled by the contrary accounts, which I find to have been given of the weight of ice and water, by no obscure writers. Thus *Helmont*, for instance, dogmatically tells us, that if a large glass-vessel, filled with pieces of ice, be hermetically sealed and balanced in a pair of scales, we shall find the thaw'd liquor weigh almost an eighth part more than the ice. Tho' we have already manifested the falsity hereof, yet for further confirmation, we several times, on purpose, weighed ice frozen and thaw'd, without finding any reason to doubt that *Helmont* was mistaken; and particularly having filled a wide-mouth'd glass with solid fragments of ice, both together amounting to a pound weight, I whelm'd over the mouth of it, another flat-bottom'd glass, so that if any vapours should ascend, they might be condensed into drops; this ice being thaw'd in a warm room, no drops appear'd on the inside of the inverted glass; when the other being put into the same scale, appear'd almost exactly of the same weight as before; tho' the ice alone, that had been resolved, amounting to much above eight ounces, ought, according to *Helmont's* proportion, to have been augmented by a whole ounce at least. And I make no doubt, that if the experiment had been tried with a greater quantity of ice, the event would have been very little, if at all, different. But I purposely chose to make my trials in no great quantities of matter, because 'tis very difficult to provide scales strong enough to weigh them without being injured; and yet prove accurate enough to discover such small differences as are fit to be taken notice of in such experiments. Mistakes in these statical trials may easily happen, unless great care be used. When open vessels are made choice of to freeze water in, 'tis no wonder that the ice weighs less than the fluid; because some of its parts will then fly away in congelation. Thus a porringer of water, set to freeze in the open air, I once observed to lose fifty grains, and another sixty; but making the like trial in a close pewter pot, we found not the difference of a grain between the ice and the water, into which it was dissolved. But that even ice, as well as water, may exhale in frosty weather, is prov'd by this experiment. Having placed several lumps of solid ice in a porringer, which together weighed a pound, and exposed them in the same scales wherein they were weighed, to the free air of a very frosty night, we found the ice had lost, next morning, twenty four grains of its weight: the weather continuing excessive cold, we kept the ice out of the sun, in the same scales all day, and a large part of the following night, and then, weighing it the second time, found that the whole decrease of weight amounted to two drams, five grains, tho' the weight of the ice, without the porringer, were but about seven ounces. And when we had kept about thirteen ounces of ice exposed to the air in a very frosty night, it had lost, the next morning, above two drams of its former weight.

9. The like experiment we made with snow as follows.

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Four ounces of snow, made up into a lump, and counterpoised in a pair of good scales, were exposed in a frosty night, after eleven a clock, without being taken out of the balance; the next morning between nine and ten, there appeared a decrease of twenty nine or thirty grains, which seem'd to have evaporated from the snow it self; for tho' a small portion of it were melted in the scale, yet that amounted not to eight grains, which was not a third of the weight the snow-ball had lost. But supposing the decrease would be greater, if the snow had a larger superficies in proportion to the bulk thereof, I caused the following trial to be made. Two ounces of snow, made up into a flat cake, being exposed all night, which was frosty, in the balance; there appeared, next morning, about eight a clock, to have been lost fifty-five grains, tho' no water was found in the scale; and about two hours after, the decrease was found to be about sixty three grains, none of the snow still appearing to have melted in the scale.*

XXIV.

I have at several times made different experiments to discover whether congelation would, by constringing the pores of bodies, vitiating their texture, or arresting the motion of their parts, hinder them from emitting those effluvia that we call odours.

Promiscuous experiments and observations upon cold.

I. Having in the months of *December* and *January*, whilst the weather was frosty, gathered different sorts of flowers, I could scarce perceive any smell therein; indeed, most of them were flaggy, and seemed ready to wither: but a primrose, that was vigorous and fresh in its kind, had an odour that was manifestly sweet and genuine.

I put, also, about an ounce of rose-water into a small vial, and after having smelt thereto, it was exposed to freeze in the open air; and when it began to freeze, I smelt to it again; but found the perfume scarce

* *M. Gauteron* observed, during the great frost at *Montpellier*, in the year 1708. that liquids evaporated much faster than when the air was temperate. An ounce of water exposed all night to freeze in a *China* vessel two inches in diameter, had lost in the morning twenty four grains; and after it was thaw'd, the water wanted twelve grains of its weight; tho' he was exceeding cautious to prevent a second evaporation. Common water, oil of nuts, oil of turpentine, spirit of wine, oil-olive, and quick-silver, being exposed after the same manner, and in the same quantity, the water presently froze, and lost six grains in an hours time; the oil of nuts eight grains, the spirit of wine and oil of turpentine, each of them twelve grains in an hour; but the oil-olive and the mercury, appeared to have rather increased

in their weight. Next morning the frozen water had lost thirty-six grains; the oil of nuts, which remain'd unfrozen, forty grains; the spirit of wine and oil of turpentine, which also were not frozen, fifty-four grains each; but the mercury and oil-olive, continued nearly as they were. This gentleman found even the hardest ice evaporate so fast, that in twenty four hours it lost about one hundred grains. And in the coldest night of this frost, which he says was the most extreme that had ever been felt in that country, the liquor of a common thermometer, being wholly reduced into the ball, the water lost forty-eight grains, the oil of nuts fifty-four, and the oil of turpentine and spirit of wine each seventy-two grains. *Memoir. de l'Academ. A. 1709. p. 584.—588.*

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PHYSICS.

at all abated; and lastly, having suffered it to continue in the air that was then very sharp, till quite congealed, the ice was not destitute of a grateful and genuine scent, tho' it seem'd somewhat faint; and even after the ice was again reduced to water, the fragrantcy appeared considerable.

But care must be had in trials of this nature, to make an early estimate; for if too much time be spent herein, there is danger that the warmth of one's breath and face may relax the pores, or thaw the surface of the ice, and both free and excite the scented corpuscles; whence, instead of ice, a liquor would be smelt to. Thus having procured some rain-water that had been kept in a tub, till it stunk so strongly, that I could hardly endure it near my nose, I caused a porringer full of it to be exposed all night to a very sharp air, and examining it next morning, when it was all turn'd into ice, neither I, nor others to whom it was offered, could perceive any stink at all in it; but having in another place repeated the experiment with as stinking water, when the porringer was the next morning brought to my bedside, I found it stink abominably; for the warmth of the room had thaw'd the superficial parts of the ice: but exposing the vessel with that liquor in it to the cold air again, an ice was produced that we found perfectly inodorous. And I remember that one of these parcels of ice being thawed, it seem'd to be less fetid than before it had been frozen. And if I had not been diverted, I should have tried whether this ice, that did not emit odours, would, like other ice, afford effluvia discoverable by the ballance; for whether it lost of its weight or not, the event might afford a considerable hint.

2. We also attempted to discover the effect of congelation upon several other qualities; not only those that are reputed manifest, as colours and tastes; the latter whereof we sometimes found to be considerably changed for the worse in flesh; but also those that are usually term'd occult; particularly, I had a mind to see whether the purging faculty of carthartics, would be advanced, impaired, or destroyed thereby: and for this purpose, I caused several purging liquors to be exposed to the cold, some of a more mild, and others of a brisker nature, in the forms of syrup, decoction, infusion, &c. but for want of opportunity to try, upon the bodies of animals, what change the cold had made in them, I was unable to satisfy my self herein: only, as in some of these trials, I made use of purgative liquors prepared by fermentation, I shall add, that fermentation is so noble and important a subject, that the influence of cold upon it deserves a particular inquiry.

That this influence may be very considerable, seems probable to me from having observed, upon trial, that raisins and water did not, in many days, whilst the weather continued very frosty, so much as begin to ferment, tho' the water were kept fluid; and that beer will continue

tinue new, as it were, and unfit for drinking, much longer than could readily be suspected, if very frosty weather happen before it has finished its fermentation. And an experienced person assured me, that such liquor would not sometimes in five or six weeks of very frosty weather, be brought to such a degree of ripeness, as one week of warm and friendly weather would give it. Nay, if I am rightly inform'd, the way to keep wine in the state of must, is to take the juice of grapes newly pressed, tun it up before it begins to work, and let down the vessel, very carefully closed, to the bottom of some deep well or river, for six or eight weeks; during which time, the liquor will be so well settled, in its accustomed constitution, that it may afterwards be kept in almost the same state, and for several months continue its sweetness.

3. Tho' the schools define cold by the property they suppose it has to unite heterogeneous and homogeneous substances; I attempted to make some separations in bodies by the force of it. For if it holds true in this climate, which has been observed in more northern regions, that a very strong spirit and a phlegm are obtainable from beer and wine by congelation, it seems probable, that in several other liquors, the watery part will begin to freeze before the more spirituous and saline ones; and if so, we may be assisted to make some separations as well by cold as by heat, and rectify some liquors by congelation, as well as by distillation: but I doubt whether the ordinary frosts of this country afford a degree of cold, capable of making such divisions and separations in bodies as have been observed in the more northern climates. However, having purposely hung out a glass-bottle of beer, in an extraordinary sharp night, I found, the next morning, that the greatest part of the liquor was turned into ice, while there remained at the bottom an uncongealed part, which to me, and others, seemed stronger than the beer, and was, at least, manifestly stronger than the thaw'd ice, which yielded a spiritless liquor. But in some other trials my success was not so considerable. For having put one part of highly rectified spirit of wine, and about five or six parts of common water, in a round glass plac'd in ice and salt; tho' the mixture was in great part turned into ice; yet I could not perceive that the two liquors were accurately separated from one another; tho' the spirit of wine employed, was before-hand deeply tinged with cochineal; and therefore I the less wonder, that in claret, I could not make any exact separation of the red and the colourless parts. But, I remember, spirit of vinegar, being exposed to the cold in a large glass vessel, a considerable part was turned into ice; which, by swimming, shew'd it self to be lighter than the fluid. The frost once seemed to have promoted a separation of cream; and another time, there seemed to be a different separation made in the parts of milk, by congelation; yet for want of leisure to prosecute such trials, they proved unsatisfactory; as did also some attempts of the like nature, made upon blood by freezing it.

PHYSICS.

it. But notwithstanding these discouragements, I resolv'd to try what I could do by this means upon brine, in order to free it from its phlegm, which might prove an advantageous experiment. For 'tis esteem'd one of the best methods to save the charge of fuel in making salt, to run their water thro' large bundles of brush-wood, that being thereby spread into a great surface, some of the pure aqueous parts may exhale away. Dissolving, therefore, one part of common salt in forty-four times its weight of common water, that it might be reduc'd to the degree of saltiness, that has been by several writers observ'd in the water of our neighbouring seas; and having likewise caus'd another much stronger brine to be made, to bring it near that of many of our salt-springs; we expos'd these solutions to the congealing cold of the air in frosty weather, when the latter, being too strongly impregnated with the salt, continued some days and nights wholly uncongeal'd; but the weaker solution being expos'd in a shallow and wide-mouth'd vessel, the large superficies contiguous to the air, afforded us a cake of ice, which being taken off, and the rest of the liquor expos'd again to the air in the same vessel, we obtain'd a second cake; and taking the remainder, which seem'd to be indispos'd to congeal farther, we found, by comparing it with what was afforded by the first cake of the ice permitted to thaw, a manifest difference; this scarce tasting so much as brackish, whilst the liquor that continued uncongeal'd was considerably salt. And by examining these two liquors hydrostatically, the difference between them also appear'd considerable; but this not being done with accuracy, I could make no estimate of the advantage, that might arise from the operation of cold, towards freeing the brine from its superfluous moisture. I had not here a sufficient quantity of ice to satisfy me, whether its little brackishness proceed from some saline corpuscles, that concurr'd to constitute the ice itself, or only adhered to the lower part of it, among other particles of the liquor that remain'd uncongeal'd. 'Twere not perhaps amiss to try, whether, in very large vessels, this experiment, promoted by some expedients that practice will suggest, may not, in some seasons and places, be turn'd to advantage.

4. I took several vegetable substances, of different kinds, as turneps, carrots, beets, apples, and tender wood, fresh cut from growing trees; as also many animal substances, musculous flesh, livers, brains, eyes, tongues, &c. and expos'd them to a very sharp cold, that they might be thoroughly frozen. One of the chief things I propos'd to myself in this attempt was, to try how far I cou'd, by congelation, discover the texture of animals and plants unregarded by anatomists; and which cou'd scarce otherwise be render'd visible. And accordingly, I found that in many succulent bodies, both vegetable and animal, the sap or juice that was so dispers'd among the other parts, and divided

vided into such minute portions, as not to be manifestly distinguish'd, might, by congelation, be both discern'd and separated from the rest. For in several plants, I observ'd the alimantal juice to be congeal'd into vast multitudes of distinct corpuscles of ice, some of which, when the bodies were transversely cut, and left a while in the open air, might be scrap'd off from the superficies of the body, whereon it wou'd after a while appear in the form of an efflorescence, almost like meal: but in others, I took a better course; for, by warily compressing the frozen bodies, I cou'd presently make the icy corpuscles start in vast numbers out of their little pores; and tho' some of these were so minute as to require an ordinary magnifying-glass, yet in other bodies, and especially in carrots and beets, the icy corpuscles were big enough to be distinctly and separately view'd; so that I rightly conjectur'd both the figures and sizes of these little pieces of ice, might be guess'd at by the shape and magnitude of the pores left in the more stable part, or parenchyma of the root. But in making an estimate of these cavities, as well as in discovering the order wherein they are ranged, I found it useful to cut the frozen roots sometimes lengthwise, and sometimes a-crofs. For by that means there wou'd appear in large carrots, for example, a great disparity in the order of the pores, which, when the root was divided by a plain parallel to the basis, seem'd plac'd in almost streight lines, tending from the centre to the circumference; but if it were slit from one end to the other, the icy corpuscles and pores wou'd seem rang'd in a very different order.

I must not here omit, that as I many years since made an experiment of freezing the eyes of oxen, and other animals, whereby the soft and fluid humours of that admirable organ may be so harden'd, as to become tractable to the meaner anatomists; so on this occasion I apply'd that experiment to the brains of animals, which tho' too soft to be easily dissected, may by congelation be made every way manageable. In dissecting the brain thus harden'd, it sometimes seem'd that the knife cut thro' multitudes of icy corpuscles; the substance of it appear'd also to the eye to be stuff'd with them, and the ventricles to harbour pieces of ice, and were perhaps filled up with them. And methinks the manifest difference of texture that there is, between the white and yolk of a thoroughly frozen egg; betwixt the crystalline, aqueous and the vitreous humours of the eye, wherein by congelation the crystalline alone loses its transparency, but acquires no conspicuous ice, whilst the other are full of diaphanous ice; with the like disparities, may afford improvable hints to sagacious anatomists.

We formerly observ'd, that congelation commonly spoils or impairs eggs, apples, flesh, &c. let us see now in what cases we may give a mechanical account of this phenomenon. Tho' the immersion of fro-

PHYSICS. zen bodies in cold water be allow'd to recover them with less prejudice, than if they were hastily thaw'd by the fire, or spontaneously in the air; yet there have been complaints made, that notwithstanding this expedient, several bodies are much the worse for being once frozen thoroughly. Since then I have shewn, that in many solid bodies the alimantal juice is by congelation turn'd into ice, and have evinc'd that water, and aqueous liquors, are expanded by congelation; I see not why the innumerable icy corpuscles, into which the alimantal juice is turn'd by the frost, being each of them expanded proportionably to their respective magnitudes, may not only prejudice the whole, by having their own constitution impair'd, as has been formerly observ'd in alicant and other vinous liquors; but also upon their expansion crush in some places, and distend in others, the more stable parts, in whose cavities they were harbour'd, and thereby so vitiate their texture, as to impair some of their qualities, and dispose the composition to corruption.

How greatly contusion may prejudice tender bodies, and accelerate putrefaction, is evident in many fruits, especially the more tender ones, which having been bruise'd, quickly begin to rot in the injured parts; and 'tis agreeable to what has been formerly shewn, that in congelation there happens innumerable little contusions made by the fluid parts, harden'd and expanded by the frost, of more stable ones, every where intercepted between them; and tho' these icy corpuscles be small, yet the sides of the firm matter that separate them, and which they endeavour to stretch or crush, are often proportionably thin. And we have seen not only that eggs will burst by having their alimantal juice frozen, but that both shingles and stones may have their texture spoil'd, by the congelation of the mineral sap, that is, in exceeding minute and insensible particles, dispers'd thro' them. And the violation of the texture of plants, herbs and animals, by the expansion of the aqueous and juicy particles, which abound there, will seem less surprizing, if it be remember'd, that a few ounces of water congel'd, will burst thro' glass, pewter, brass, or iron.

Whilst I was upon these trials, I had also a desire to know, whether by freezing animals to death, any such change in the qualities or structure of their parts cou'd be discover'd, as might lead us to the means whereby excessive cold kills men in northern countries. I expos'd a young rabbit all night to a very vehement frost, without finding any other damage, than one of his legs swell'd and grown stiff. But in a rabbit purposely strangled, and presently expos'd intire to a severe degree of cold, we found ice produc'd in such parts as wou'd have caus'd us to prosecute the experiments, had not the want of such animals hinder'd us.

It is affirm'd by some eminent modern writers, that water impregnated with the saline parts of a plant, and afterwards frozen, will exhibit

hibit in the ice the shape of that plant. Nay, the learned *Gaffarel* tells us, that this is no rarity, being daily shewn by one *M. de la Clave*. We therefore lately try'd what cou'd be done with decoctions, that were richly imbued and highly ting'd with the spirituous parts of the vegetables; but the ice was by no means so figured as the tradition promises: and I remember, that having made a lixivium with sixteen parts of water, and one of the salt of pot-ashes, and expos'd it in a thin glass-vial to an exceeding cold air, we found much ice produc'd thereby, that lay on the top in little sticks, not unlike those prismatical bodies into which salt-peter shoots; and the parts of this ice that were beneath the water shot into thin parallel plates, exceeding numerous, but nothing resembling trees, by the incineration whereof *Polonian* pot-ashes are made.

Bartholine, indeed, says, that the water wherein cabbage has been boiled, will, when frozen, represent a cabbage; the vegetable spirits being, as he supposes, concentrated by the cold. How well this experiment may succeed when made in a cold country I know not; but filtering a strong decoction of cabbage thro' cap-paper, we froze it in a thin glass-vial by means of snow and salt; the ice did not either appear to have any thing in it like a cabbage, or remarkably different from other ice. And we afterwards expos'd a decoction of the same, to be congeal'd by the nocturnal air; but neither this way did the experiment succeed. And tho' once a few ounces of the decoction being lightly frozen in a vial, there appear'd in the thin ice that adher'd to the inside of the glass, a figure not very unlike that of a cabbage-leaf; (and perhaps some such accident may have invited our learned author to think, that the representations of cabbages wou'd constantly appear in their frozen decoctions;) yet this configuration seem'd only casual; for by freezing the decoctions of several herbs, some of them spirituous enough, as rosemary, penny-royal, &c. the ice I obtain'd from them, gave me no conviction of the truth of the tradition we are examining. On the contrary, I have, more than once, by freezing fair water after a certain manner, obtain'd ice, that seem'd much more to resemble vegetables, than any decoctions of them that I ever try'd. And particularly, I sometimes found, that by putting hot water into a slender glass cylinder, and agitating it in our frigorific mixture, so that it was very speedily frozen thereby, it was congeal'd into an ice much more regularly and prettily figured than I have seen from the waters impregnated with the fixed salt of plants, or even of nettles; tho' that is so much boasted of. In short, a luxuriant fancy may produce apparitions in ice, which a more judicious observer cannot see. That a vast variety of figures are produced by congelation, no body denies; the same, also, happens in chymical preparations, and they will sometimes appear regular; but 'tis plain, their generation is purely casual.

PHYSICS.

'Tis remarkable, that while the cold has strange and tragical effects at *Moscow*, and elsewhere, the *Russians* and *Livonians* should be exempt from them, who accustom themselves to pass immediately from a great degree of heat, to as great an one of cold, without receiving any visible prejudice thereby. I remember, being told by a person of unquestionable credit, that it was a common practice among them, to go from a hot stove into cold water; the same was, also, affirmed to me, by another who resided at *Moscow*: this tradition is likewise abundantly confirmed by *Olearius*. " 'Tis a surprizing thing, " says he, " to see how far the *Russians* " can endure heat; and how, when it makes them ready to faint, they " go out of their stoves, stark naked, both men and women, and throw " themselves into cold water; and even in winter wallow in the snow."

I had several years since the curiosity to try, whether there were any truth in the tradition, that the rays of the moon are cold; but notwithstanding all my care to make trials in clear weather, when the moon was about the full, and with the assistance of a thermometer, I could not perceive, by any concentration thereof, even upon a black object, that her light produced any sensible degree either of heat or cold: but, perhaps, others with very large glasses may be more successful. I cannot, however, help suspecting, that the learned physician *Sanctorius*, mistook in asserting the light of the moon to be considerably hot, when thrown thro' a burning-glass upon the ball of a common weather-glass; whereby, he says, the water was considerably depressed, as appeared to many of his disciples, in a circle of whom the observation was made. For my glass was much better than his seems to have been; and my trials were, perhaps, as carefully and impartially made as his. But, probably, his scholars, whilst they stood round his thermometer, and stooped to see, by so dim a light, the event of the experiment; the unheeded warmth of their breath and bodies might, unawares to *Sanctorius*, affect the air included in the weather-glass, and cause that depression of the water, which he ascribed to the moon's heat.

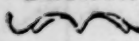
We took a sealed weather-glass, about ten inches long, furnished with spirit of wine; and having caused a hole to be made in the cover of a box, just wide enough for the smaller end of the glass to be thrust in at, we inverted the thermometer into it, so that the ball rested upon the cover, and the point tended directly downward; then we placed about the ball, a little ice and salt, and thereupon observed the tinged spirit, in a very few minutes, to ascend above an inch higher than its former station; and it would, perhaps, have risen farther, if the application of the frigorific mixture had been continued: by which, and another succeeding experiment, made to the same purpose, it seems the condensation of liquors by cold, is not always effected by their proper gravity only, which may usually suffice to make the parts fall closer together: but whether in our case, the contraction be assisted by some little tenacity in the liquor, or by the spring of some little aerial or other spirituous

spirituous and elastic particles, from which the instrument was not perfectly freed when sealed up, or which happened to be generated within it afterwards, remains to be enquired into. PHYSICS.

There is a famous tradition in *Muscovy*, and some other cold countries, that 'tis usual, out of ponds and rivers, to take great numbers of benum'd swallows, inclosed in pieces of ice; upon thawing whereof, in a warm room, the birds come to themselves, and fly about amazedly for a while, but not long survive so great and sudden a change. This phenomenon I have been assured, by a person of honour, who was commanded by a great prince to inquire into the truth of it, was affirmed to him as certain by the most eminent and sober persons he could meet with. And an intelligent person of quality in *Poland* acquainted me, that in the parts where he liv'd, it was a very general and unquestion'd opinion, that such birds often hid themselves, all the winter, under water, in ponds, lakes, and sedgy places, and that the fisher-men draw them up in the manner already mentioned. But as for their being taken up in ice, he told me, he had not heard of it; tho' I see not why, in case they commit themselves to shallow waters, as those of ponds and sedgy places often are, a sharp lasting frost may not, sometimes, reach them. And, therefore, what left me the greatest scruple about this tradition, was, that this curious gentleman could not affirm, he had ever seen any example of the thing he related.

It is a tradition handed down and received from *Aristotle*, that hot water will sooner freeze than cold. But I could never find any truth in the assertion.

We took three porringers near of the same size, and filled one with cold water, another with water that had been boiled, but was now moderately cool, and a third with hot water, and exposed the three together in the same place, to the freezing air, at half an hour after eight a clock, and found the porringer of cold water began to freeze at $\frac{1}{4}$ after ten. That which contained the water that had been heated and cooled again, began to freeze at $\frac{1}{4}$ past ten; and that which contained the hot water, at half an hour after eleven; so that all froze within the compass of two hours: yet the cold water began to freeze an hour and a quarter sooner than the hot. These were earthen porringers, but I also made the experiment in others of metal; and then, too, the cold water began to freeze, both before that which had been heated, and cooled again, and long before the hot. Another time I measured the water out by spoonfuls, into porringers, that the quantities of water might not be considerably unequal; and then, also, the cold water froze a considerable while before the hot. Upon repeating the experiment with greater caution, the cold water being put out with the rest at $\frac{1}{4}$ after six, it began to freeze before $\frac{1}{2}$ an hour after seven. The water heated and cooled again began to freeze at $\frac{1}{4}$ after seven; and these having stood for a pretty while by me, I sent for the hot water, and found it not to be in the least

PHYSICS.  least frozen at half a quarter after eight. So that supposing it to continue half a quarter of an hour longer, before the beginning of its congelation, as it afterward did at the least, it was twice as long, ere it began to freeze, as the cold water had been. By which we see how well their labour was bestowed who have puzzled themselves and others to assign the reason of a phenomenon that might easily have been found upon trial to be chymical.

I have been the more circumstantial in these trials, that I might express a civility to *Aristotle*; and because artificial congelations are not so proper for this purpose. For having formerly taken two pipes of glass made on the same cylinder, that they might be of an equal bore, sealed each of them at one end, filled them to the same height, and then stirred them together in a mixture of beaten ice, water and salt, I found both parcels of water to freeze too suddenly, to shew a notable disparity in the time they remain'd uncongealed. Having made the same experiment with slender glass pipes, and for greater caution, put the hot water first into one glass, then into the other, we once found that the hot water froze first; which wondering at, we examined the glasses, and perceiving one of them to be more conical where it had been sealed than the other, it appeared that the water in this part, being suddenly frozen by reason of the slenderness of the glass, there accelerated the congelation of the rest.

'Tis said, indeed, by a commentator upon *Aristotle*, that his experiment will succeed, if by heated water we understand water that has been heated and suffered to cool again, till it be reduced to the temper of other cold water; for this refrigerated water, he says, he has found to congeal much sooner than the other sort. But this, I confess, I am very unapt to believe. For having often caused cold water to be exposed to the air in frosty weather, together with some which had been heated and cooled again, the events did not answer this assertion; tho' due regard was had to the most considerable circumstances in such an experiment. But for farther satisfaction, we took two porringers of the same size and shape, one of which, we almost filled with common cold water, and the other with an equal quantity of such as had been heated and cooled again; this done, I appointed one to examine the tempers of these waters with an exact weather-glass; and being both reduced to the same temper, they were exposed to a very sharp air, and watched by the same person, who finding them begin to freeze, as it were at the very same instant, brought the two porringers to me, in each of which, I saw the bear beginning of congelation in the upper surface of the waters, where they were contiguous to the containing vessels.

It is a current, and almost universal tradition, that when ponds or rivers are frozen over, unless the ice be seasonably broke in several places, the fish contain'd therein will die for want of air; but whether this be well grounded, I dare not determine till farther trial has been made: for that fish cannot live without any more air than they find interspersed

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in the water where they swim, has not, that I know of, been sufficiently prov'd; and, possibly, there may be other reasons assign'd of the death of the fish in ponds frozen by very sharp frosts. For who knows what the locking up of some kinds of subterranean steams, that freely ascend thro' fluid water, may do towards vitiating and infecting it? Perhaps, also, the excrementious steams that insensibly issue out of the bodies of the fish, may, by being pent up, contribute, in some cases, to render the water noxious. For being desirous to learn, from a person curious in preserving and transporting fish, whether some fish would not quickly languish, grow sick and die, if the water they swam in, were not often shifted; he assured me, some kinds of them would: and it has not yet, that I have heard of, been tried, whether, tho' ponds seldom freeze to the bottom, yet the water that remains under the ice, may not, even whilst it continues uncongealed, admit a degree of cold, that tho' not great enough to turn water into ice, may yet destroy fish within less time than the surface of a pond often continues frozen.

To try whether ice, by denying access to the air, would destroy fish, I procured a glass vessel with a large belly, and a long slender neck; and having filled it with water, and some live gudgeons, we pass'd the neck of it thro' a hole that was made in the midst of a metalline plate; which served also to support a mixture of ice and salt, applied round about the extant parts of the glass. By this contrivance, I propos'd to myself a double advantage; first, that as in broad vessels, one cannot, easily, be certain that the surface of the water is quite frozen over in every part, I could thus satisfy my self of that, by inverting the glass, and observing that the ice had so exactly choaked up the neck, that not a drop of water could get out, nor any bubble of air get in, and yet the fish have liberty to play in the subjacent waters. Secondly, the frigorific mixture, being here applied to the neck, none of the water was congealed, or extremely refrigerated, but that which lay in the neck; so that there seem'd no cause to suspect, that if the fish should die in the water, it was rather cold than want of air that killed them. But having not prosecuted these trials, to the utmost, I shall lay no great stress upon them; yet I remember that the included fish, at this time, continued long enough alive, to make me strongly suspect the truth of the vulgar opinion.

I afterwards caus'd some of the same kind of fish to be put into a broad and flat earthen vessel, with but little more water than sufficed to cover them; and having expos'd them all night to a very intense degree of cold, I found them the next morning alive, and seeming not to have been much prejudic'd, either by the cold, or exclusion of air. 'Tis true, there was a very large moveable bubble under the ice, that seem'd to have been generated by the air, or some analogous substance, emitted out of the gills, or bodies of the fish; for the surface of the water was exactly frozen over. And that this bubble might possibly proceed

PHYSICS.

proceed from the fish themselves; I the rather suspect, because, having, at different seasons of the year, kept several sorts of fish, for many days, in glass vessels, I have often seen them raise their mouths above the surface of the water, and there seem to gape for air, and afterwards let go, under water, out of their mouths and gills, several bubbles, which seem'd to be portions of the air they had thus taken in. And particularly, in lampries, I have with pleasure observed, that being taken out of the water into the air, and then held under water again, they very manifestly appeared forcibly to squeeze out of those several little holes which are commonly mistaken for their eyes, numerous bubbles of air. But to satisfy my self further what degree of cold and want of air these gudgeons might support, I exposed two of them in a basin of water, to an exceeding sharp night, and the next day found the ice frozen in the vessel, to a great thickness, and one of the fish frozen up in it, while there remain'd only a little of the water unfrozen, wherein the other fish swam: and the ice being afterwards partly thaw'd and partly broken, not only the latter was found very lively, but the other, which tho' when the ice was broke, it lay moveless, did, in a few minutes, so far recover, as to drag after it a large piece of ice, into which its tail remained inserted. And tho' one of these, and some other gudgeons that had been already weakened, by long keeping, were once more exposed to the frost, in the basin, and suffered to lye there till they were frozen up; yet the ice, in which they were inclosed, being broken, their bodies were grown stiff and crooked, and seem'd to be quite dead, for they lay upon their backs in the water, yet one of them quickly recovered, and the other, not very long after, began to manifest signs of life; tho' he could not, in many hours, so far recover, as to swim upon his belly. 'Tis true, that these fish did not long survive; but two or three probable reasons might be assign'd for that; and particularly the ice they had been frozen up in had wounded them, as was manifest by some hurts that appeared upon their bodies. Some other gudgeons were irrecoverably frozen to death, by being kept inclosed in ice for three days. I likewise caused a couple of frogs; to be artificially frozen in a wide-mouth'd glass, furnished with a convenient quantity of water; but tho' they seem'd, at first, to be inclosed in ice, yet looking nearer, I found that about each of them there remained a little turbid liquor unfrozen; as if it had been kept so by some expirations from their bodies. Wherefore causing them to be carefully frozen, and for a considerable time, I found, that notwithstanding the ice, into which most part of the water was reduced, one of them, before the ice was perfectly broken, appeared to be alive; but the other lay moveless, stiff, and with the belly upwards, in a basin of cold water, wherein it lay cast; tho' in a very few minutes, he began to swim about therein. Upon the whole, tho' the tradition we have been examining, may, perhaps, have something of truth in it; yet it seems to deserve a farther inquiry, both in regard

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to the matter of fact, and to the cause of the effect.

That snow, lying long on the ground, greatly conduces to the fertilization thereof, is a common observation of our husbandmen; and *Bartholine*, in his treatise of the use of snow, brings several passages out of authors to make it good; to which I shall add the testimony of *Dr. Fletcher*, who speaking of the fruitfulness of the soil in *Russia* says, "this fresh and speedy growth in the spring, seems to proceed from the snow; which, during the winter, being spread over all the country, keeps it warm from the frost; and in the spring, thoroughly drenches and soaks the ground, which is of a sandy nature."

I thought it might give some light into the nature of cold, to try whether two liquors, by being mixed together, and losing their fluidity, so far as to obtain the consistence of an unguent, would produce any sensible degrees of that quality. This I attempted by immersing, for a competent time, the ball of a tender sealed weather-glass, into each of the liquors apart; and then into the soft mixture, composed by their union. But tho' a strong solution of minium, or calcined lead in spirit of vinegar, or a very strong infusion of good quick-lime in water, will, either of them, coagulate a just proportion of good fallet oil into such a consistence; yet for want of a sealed thermometer, sufficiently tender, I cannot now repeat the experiment; therefore dare not draw any conclusion from it: tho' if I remember well, upon shewing one of these mixtures to an ingenious person, neither he nor I could perceive, that the liquors, by being deprived of their fluidity, had required any degree of coldness, discoverable by a sealed weather-glass.

XXV.

It has long been supposed agreeable to the wisdom of nature, that cold and heat should both of them be endued with a self-invigorating power, which each might exert when surrounded by its contrary; and thereby prevent their mutual destruction. Thus 'tis supposed, that in summer, the cold expelled from the earth and water by the sun's scorching beams, retires to the middle region of the air, and there defends it self against the heat of the superior and inferior. And thus, also, in summer, when the air about us is sultry hot, we find, that cellars and vaults, have the opposite quality; so, in winter, when the external air freezes the lakes and rivers, the internal air, in the same vaults and cellars, becomes the sanctuary of heat: and water, fresh drawn out of the deeper wells and springs, in a cold season, not only feels warm, but manifestly smokes. And having purposely inquired of ingenious men, who had been very deep under ground, some in coal-pits, and some in mines, one of them affirmed, that at the bottom of a groove, he found it very hot in September; another, that he often, in such places, found it hot enough to be troublesome in winter; and a third, who is a master of mines, that he found them hot all the year long. And to manifest, that such ob-

The vulgar notion of an antiperistasis examined.

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And having purposely inquired, whether, in the winter, he found it as hot in cellars at *Moscow*, as it usually is in that season in ours; he answered, that when the doors and windows were carefully shut, to hinder the immediate commerce betwixt the included and external air, he often found, if he stay'd long in his cellar, it would not only defend him from the sharpness of the *Russian* cold, in winter, but keep him almost in a sweat, tho' he laid aside his furs. So that if we may rely upon the testimony of our senses, 'tis argued, we must necessarily admit cellars to be warmer in winter than in summer, and consequently allow an *Antiperistasis*.

But considering the reason of the thing abstracted from the experiments that are pretended to prove an *Antiperistasis*, it seems very rational to reject it. For in the first place, according to the course of nature, one contrary ought to destroy, not to strengthen another. And next, 'tis a maxim, that natural causes always act as much as they can. And certainly, as to our case, wherein we treat not of living creatures, I cannot but think the axiom physically demonstrative. For inanimate agents act not by choice, but by a necessary impulse; and not being endow'd with understanding and will, they cannot, of themselves, be able to moderate or suspend their actions. Nor is there any danger, that cold and heat, whose causes are so rooted in nature, should be lost in the world, tho' each parcel of matter, that happens to be surrounded with bodies, wherein a contrary quality reigns, were not endowed with an incomprehensible faculty of self-invigoration. And nature either does not need the help of this imaginary power, or often has recourse to it to very little purpose: since we see, that tho' these qualities subsist in the world, yet, in fact, bottles of water, wine, and other liquors, carried up and down in the summer, are regularly warmed by the ambient air. And in *Muscovy*, and other cold

cold northern countries, men, and other animals, have often their vital heat destroyed by the cold that surrounds them, being thereby actually frozen to death. And I wonder, that the followers of *Aristotle* should not take notice of that famous experiment, whereby he pretends, that hot water will sooner congeal than cold. For if the matter of fact were true, it would sufficiently manifest, that the heat harboured in the water, is destroyed, not invigorated by the coldness of the air that surrounds it. And tho' it is true, that white surrounded with black, or black with white, becomes thereby the more conspicuous; yet 'tis acknowledged, that there is no real increase, or intensification of either quality, but only a comparative one in regard to our senses, obtained by this comparison. Nor does a pumice-stone grow more dry than it was in the fire or earth, by being transferred into the air or water; and consequently surrounded with either of those two fluids, which the schools teach to be moist elements: neither will a piece of dim glass become really more transparent, tho' one should set it in a frame of ebony. 'Tis commonly, indeed, alledged, as a proof of the power nature has given bodies of flying their contraries, that drops of water, falling upon a table, will collect into little globes, to avoid the contrary quality in the table, and keep themselves from being swallowed up by the dry wood: but the cause pretended, has no interest in the effect; for little drops of water, where the gravity is not great enough, to surmount the action of the surrounding fluid, if they meet with small dust upon a table, gather it up as they roll along, and their surfaces being covered with it, do not immediately touch the board, which else they would stick to. And to shew that the globular figure, which the drops of water, and other liquors, sometimes acquire, proceeds not from their resisting of dryness, but either from their being every way press'd, at least, almost equally by some ambient fluid, of a disagreeing nature, or from some other cause differing from that the schools would assign; the drops of water which swim in oil, so as to be surrounded with it, will be, likewise, globular; yet oil is a true moistening liquor as well as water. And the drops of quick-silver, tho' upon a table they are more disposed than water, to gather into a round figure, yet that they do it not as humid bodies is evident; because quick-silver broken into drops, will shew most of them globular, not only in oil, but in water. And that it is from the incongruity it has to certain bodies, that its drops refuse to stick to a table, but gather themselves into little spheres, as if they design'd to touch the wooden plain in a point, appears, because, tho' the same drops will retain the same figure on stone or iron, yet they readily adhere to gold, and lose their sphericity upon it; tho' gold be a much drier body than wood, which, as far as distillation manifests, must contain numerous humid parts of several kinds. But as to the *Antiperistasis* of cold and heat, the *Peripatetics* talk of those qualities being each surrounded by its opposite, as if both of them had an understanding,

PHYSICS.

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PHYSICS.

and foresight, that in case it did not gather up its spirits, and guard against its antagonist, it must infallibly perish; which is to transform physical agents into moral ones. And as reason declares against the common opinion, so experiment also may be alledged against it.

The grand experiment, which a late champion for *Antiperistasis*, makes his leading argument to establish it, and which is so generally urged on that occasion, arises from the heating of quick-lime in cold water. Now, I cannot but here admire at the laziness and credulity of mankind, who have so long, and generally acquiesced in what they might so easily have found to be false; for if, instead of cold water, you quench the lime with hot water, the ebullition will be, oftentimes, far greater than if the liquor were cold. And this might well be expected; hot water being much fitter than cold, suddenly to pervade the body of the lime, and hastily dissolve, and set at liberty the fiery and saline parts, wherewith it abounds. And what a greater interest salts may have in producing such heats than cold, I have also tried by pouring acid spirits, and, particularly, spirit of salt upon good quick-lime. For by this means there would be a far greater degree of heat excited, than if I had used common water: and this, whether I employ'd the spirit cold or hot. For in either case, so small a portion, as about the bigness of a walnut of lime, put into a small glass, would, by the gradual addition of a little spirit of salt, both hiss, smoke, and boil very surprizingly; and notwithstanding the small quantity of the matter, conceive so great a heat, that I was not able to hold the glass in my hand. And to shew how little, heat excited in quick-lime by cold water, proceeds barely from the coldness of that liquor; I caused a parcel of good lime to be beaten small, and putting one part of it into a glass vessel, I drench'd it plentifully with oil of turpentine, more than it would imbibe; the other portion I likewise drench'd with common water; and both these liquors having stood in the same room, that they might be reduced to a like degree of coldness, the event was, that the oil of turpentine, notwithstanding its actual coldness, and the great subtilty and penetrancy of parts, which it has in common with other chymical oils, being of an unfit texture, seem'd not to make any dissolution of the powdered lime; and did not, for several hours, that I kept it, produce any sensible heat therein; whilst that part on which common water had been poured, soon conceived so strong a heat, that it broke a large open-mouth'd glass, into the bottom whereof it was put; and not only grew so hot, that I could not endure to hold it in my hand, but sent out at the mouth of the glass, tho' that were considerably distant from the lime, a large white fume, so hot, that I could not bear to hold my hand over it. And to prevent an objection, which I foresaw might be raised against the experiment made with oil of turpentine, from the oleaginous nature of that liquor; I covered a piece of the same sort of quick-lime, with highly rectified spirit of wine: but tho' I left them together all night,

night, yet I perceived not, that the liquor had at all flaked the lime, which continued in an intire lump, till substituting common water, it quickly appeared to be flaked, and fell asunder into a kind of minute white powder.

In freezing a bason to a joynt-stool, with a mixture of snow and salt, by the fire-side, 'tis pretended, that the fire so intends the cold, as to enable it to congeal the water, that stagnated upon the surface of the stool, betwixt that and the bottom of the vessel. But how little need there is of *Antiperistasis* in this experiment, appears from hence, that I have purposely made it with good success, in a place where there neither was, nor ever probably had been, a fire: and this trial I could confirm by several other experiments of the like nature; but this one is sufficient.

'Tis farther delivered for fact, that if, having almost filled a large pot with snow, and placed in the middle of the snow a vial full of water, this pot be put over the fire, the coldness of the snow will be so increased by the heat, from which it flies into the water, as to turn that liquor into ice. But tho' I several times tried the experiment, yet neither in earthen, nor in silver vessels, could I ever produce the promised ice. And I remember, that a very learned man, who wondered to find me so diffident of what he said he knew to be true, readily undertook to convince me by ocular proof; but with no better success than I had before.

And in case the trial should succeed, sometime or other, yet will there be no necessity of deriving the effect from *Antiperistasis*. For tho' the fire would then contribute to the effect, by hastening the dissolution of the snow, yet the heat of the fire does but remotely, and by accident, cause the production of ice; since other agents will do the same thing, that are qualified to make a quick dissolution of the snow, whether they be hot or not; as spirit and crude salt of nitre, will, either of them, by a due application, bring snow, by dissolving it, to congeal water; tho' the spirit and the nitre be generally agreed upon to be actually cold, and one, if not both of them, to be potentially cold too.

Having thus dispatch'd the experiments pretended to prove an *Antiperistasis*, I shall next examine the observations, alledged to that purpose; of which the principal are, the coldness of the middle region of the air; the increase of men's appetite in winter; the generation of hail; and the heat and cold in cellars, and other subterranean places, when the contrary quality reigns in the air.

To begin with the first of these. I will not now dispute, whether the second region of the air, have really the coldness ascribed to it: I see no necessity, however, of employing an *Antiperistasis*, to keep the second region of the air for the most part cool. Without taking in the cause imagin'd by the schools, an obvious and sufficient one may be easily assign'd hereof. For the air being, as to sense, cold of its own nature, so

PHYSICS.

that when we feel it hot, it is made so by some adventitious agent; and that agent being, for the most part, the sun, which heats the air chiefly by its reflected rays; their heat is so languid, by that time they arrive, dispers'd, at the second region of the air, as to be unable to over-power its natural coldness, increased perhaps by some frigorific spirits, that may find a more commodious harbour there, than in other parts of the atmosphere. And whatever be the true cause of the coldness in the middle region of the air, I admire to find it so confidently ascrib'd to *Antiperistasis*, by the *Aristotelians*: for, according to them, 'tis the nature of the air to be as well hot as moist; and according to the same, both the upper region of the air always, and the lower in summer, is kept hot, the former by the neighbourhood of the imaginary element of fire, and the latter by the reflection of the sun-beams from the earth: how therefore comes *Antiperistasis* to take place here? For, as they say, those bodies have their cold and heat increas'd by *Antiperistasis*, that are on both sides assail'd by others of a contrary quality, to that which is natural to the surrounded body; but the whole element of air, and consequently the middle region, being, as they would persuade us, hot of its own nature; what shadow of probability is there, that the highest and lowest regions, by being hot, should make the middle region, which is also naturally hot, intensely and durably cold? However, it does not appear, if the air be naturally rather cold, than hot, that the second region must owe the intenseness of that quality to an *Antiperistasis*. For the ground of this opinion, being, that both the first and the third regions are considerably hot, I would gladly find it prov'd as to the upper region. 'Tis true, there are two reasons alledged, to shew the heat of the higher region of the air, but neither of them seems cogent. The first is, its vicinity to the element of fire. But if we consider the distance of that element, which they place contiguous to the orb of the moon; and how little nearer to it the concave part of the upper region is, than the convex of the middle, we may easily conceive, that in two distances, that are both of them so immense, so small a disparity cannot be more considerable, than the greater nearness of one side of a sheet of paper held at three yards distance from an ordinary fire, in comparison of the other side of the same paper; or than the distances of a small wart, and of the neighbouring parts of the face, when a man comes within two or three yards of the fire. But 'tis not worth while to prosecute this consideration, because the argument against which 'tis alledg'd, is built upon the groundless supposition of the element of fire; a figment which many of themselves are asham'd of; and indeed its existence is as little to be discovered by reason, as perceiv'd by sense.

The other argument for the heat of the third region of the air, is, that fiery meteors are kindled by it. But not here to examine, whether all meteors that shine, and therefore pass for fiery, are really kindled

kindled exhalations; we see, that in the lower region of the air, and in winter, those fires called either *Helena*, or *Castor* and *Pollux*, are generated in great storms, and hang about the sails and shrouds of ships. Nay, do not we much more frequently see, that lightning is produced at all seasons of the year; for in warmer countries thousands have observed it to thunder (and so have I in winter) in the middle region of the air? And if 'tis not the heat of the lower part of the air, that kindles those exhalations; and if, notwithstanding the coldness of the second region, fiery meteors may be frequently generated there; I see not how the production of such meteors argues the heat of the third region of the air. And if that region be not hot, then it will be easily granted, that the coldness of the second must very improperly be attributed to such an *Antiperistasis*, as it is generally ascribed to.

Let us next consider that aphoristical saying of *Hippocrates*, "the *Viscera* are hottest in the winter," together with the observation whereon it seems to have been grounded. I will not now enquire whether any arguments for the contrary may be drawn from the heat and thirst men feel in summer, and the refreshment they then find by drinks, fruits, and other aliment actually cold; what I principally intend is, that I much more doubt the matter of fact, than that, in case it be true, it may be accounted for without the help of *Antiperistasis*, in the vulgar notion of that term.

And first, the proof usually brought of the greater heat of men's stomachs in winter, is, that they then have a greater appetite. But the aphorism supposes digestion to be made in the stomach by heat; and consequently that the stronger digestion made in the winter, is an argument the stomach is then hotter than in other seasons of the year. The error of this supposition, need not be solemnly proved, since there are several things in nature, that agree not with it, and particularly the strong concoction made in ravenous fish, whose stomachs and blood are, as I have purposely observed, sensibly cold. But if it should in some cases prove true, that there is really in men's bodies a far greater heat in winter than in summer, yet this would not infer an *Antiperistasis* in the sense, wherein I oppose it. For the vital heat lodg'd in the heart, always generating out of the blood and juices, that continually circulate thro' that part, plenty of spirits and warm exhalations, which transpire thro' the pores of the skin in much greater quantities, than, notwithstanding the affirmations of *Sanctorius*, any thing but my own trials could have persuaded me; these warm steams finding the pores of the skin straitned and shut up, gradually grow more numerous in the body, and thereby heat the stomach, as well as the other internal parts. Perhaps, also, the same cooling corpuscles or temperature of the air, that produce cold in winter, may, by shutting in certain kinds of effluvia, or altering the motion or texture of the blood, reduce it to such a disposition, as shall increase the appetite,

as

PHYSICS.

as well as the concoction in the stomach, promoted by the stomachical menstruum, or ferment, which either is newly generated in winter, or more plentifully supplied (by the circulation of the blood) in that season than in others. And to shew, that a keen appetite may be procur'd by agents endow'd with very distinct and contrary qualities; aromatic fauces, wine and vinegar, all of them, in most men, beget an appetite, tho' the two former be confessedly hot, and the latter cold. And so wormwood, and the juice of lemons, have both of them frequently reliev'd dull and weak stomachs; tho' the one be confessedly a hot simple, and the other a cold one. And in some cases, either the frigorific corpuscles themselves, and perhaps some other unknown to us, brought along with them, may so sollicit the stomach, as to cause an eager appetite, not precisely by their being cold or hot, but by their peculiar nature; as we have instances of some among us, who by walking in the snow, procure an insatiable hunger. And the learned *Fromundus* relating how himself, by walking long on the snow, was surpriz'd with such a canine appetite, takes notice, that the chief cause of the fainting was in the stomach: and that he found by his own experience, that part discompos'd, twitch'd and provok'd to retchings. He adds, that he thinks the chief cause of the *Bulimia* to consist in certain steams, that peculiarly affect the stomach, which they gnaw and distend. And just before he observed, that straining to fetch deep coughs is a present remedy in this distemper, by discharging the stomach and lungs of those snowy spirits, which were either attracted in respiration, or had, some other way, insinuated themselves in those parts: so that besides the cold, abstractedly consider'd, the stomach may be peculiarly affected by other attendants of the frigorific corpuscles, that grow powerful in frosty weather. To this it well agrees, that several have been subject to a *Bulimia* in our climate, who endure nothing near so great a cold, nor are so much disorder'd by it, as multitudes of others, who in *Nova Zembla*, and other frozen regions, never complain'd of having contracted, even in the midst of winter, any such disease.

Another argument, urg'd in favour of *Antiperistasis*, is borrowed from the production of hail, which is presum'd to be generated in summer only, not in winter; and, according to the schools, is made in the lowest region of the air, by the cold of the falling drops of rain being so highly intended by the warmth it meets with in the air near the earth, as to congeal the water wherein 'tis harbour'd. But tho' I think the generation of hail hard to be well explain'd; yet I reject the receiv'd doctrine about it, for several reasons.

And first, 'tis not universally true, that hail falls not but in summer, or very hot weather; for I have myself observ'd it to hail at the latter end of *November*; and that when some frosty days had preceded, and when the coldness of the weather was complain'd of. Nay, the longest shower of hail that I remember to have seen,
fell

fell about a week before the end of *January*, on a night preceded by a very frosty day, which itself was preceded by a sharp fit of frosty weather. And when the tedious shower was over, there came to the house, where I then was, a servant to one of my domestics, and related to her master, and others, that she was mislead out of the beaten way, where the storm found her, by an *Ignis fatuus*, which she long mistook for a common light. Now, how the nocturnal air could kindle a fiery meteor by its coldness, and at the same time congeal the falling drops of water into ice by its warmth, I shall leave the patrons of *Antiperistasis* to consider; and only add, that doubtless other observations of the like kind have been often made, tho' perhaps seldom recorded: for within a very few weeks of this storm, some servants of mine affirm'd they had observed it to hail two or three times besides.

Next, if *Aristotle* hath rightly assign'd the cause of hail, 'tis somewhat strange it should not fall far more frequently in summer, and especially in hot climates, than it does; considering how often, in all probability, the drops of rain fall cold out of the second region into the warm air of the first. And more strange it is, that even in those parts of *Aegypt*, where it rains frequently enough and plentifully, tho' not about *Grand Cairo*, yet about *Alexandria* and *Pelusum*, it should never hail no more than snow, as the learned *Prosper Alpinus* affirms. Besides, as to the generation of snow in the upper region of the air, and hail always in the lower, my own observation has afforded me many instances that seem to contradict the tradition. For I have observed that in many great grains of hail, besides a hard transparent icy shell, there was, as 'twere, a snowy pith of a soft white substance; and this snowy part was most commonly in the middle of the icy, but sometimes otherwise. And lastly, the favourers of *Antiperistasis* would have the drops of rain in their descent, to be congeal'd apart in the ambient air; but the irregular and angular figures we often meet with in hail, gives little countenance to this doctrine: and hail often falls in grains too large by far to comply with *Aristotle's* conceit. For, not to mention the grains of hail I have myself observed to be of a bigness unsuitable to this opinion, several eye-witnesses have inform'd me of their having observed much greater than those I have done: and particularly an eminent virtuoso of unquestionable credit, affirm'd to me, that he had at *Lyons* in *France* observ'd a shower of hail, many of whose grains were as large as ordinary tennis-balls, and which greatly damaged the windows and tiles of the houses, answerable to that unusual bulk. And *Bartholine* declares, that he himself observ'd, in another shower of hail, grains of a larger size; a single one weighing no less than a whole pound. But tho' this itself is little in comparison of what I remember to have met with in authors; yet it abundantly suffices to disprove the vulgar conceit about the generation of hail, till we meet in these countries with showers of

PHYSICS. rain, whose single drops prove to be as large; which I presume those who ascribe hail to *Antiperistasis*, will not easily shew us.

I come now to consider the last, and indeed the principal example, that is given of *Antiperistasis*, the coldness of cellars, and other subterranean vaults in summer, and their heat in winter.

And first, as to the refreshing coldness which subterranean places afford in summer, I both deny that they are then colder than in winter; and assert, that tho' they were, that coldness would not necessarily infer an *Antiperistasis*.

We must consider then, that in summer our bodies having, for many days, or weeks, been constantly surrounded with an air, which, at that season of the year, is much hotter than in winter, or other seasons; our senses may easily impose upon us, and we be much mistaken, by concluding upon their testimony, that the subterranean air we then find so cool, is really colder than it was in the winter, or the spring; as they who come out of hot baths think the air of the adjoining rooms very fresh and cool, which they found to be very warm, when coming out of the open air, they went thro' those warm rooms to the bath. And the depth and retiredness of these subterranean caves keep the air they harbour, from being any thing near so much affected with the changes of the season, as the outward air, that is freely expos'd to the sun's rays, which pierce, with any sensible force, so little into the ground, that diggers seldom observe the earth to be dried and discolour'd by them beyond the depth of a very few feet. And I have found, in very shallow mines, not above six or seven yards deep, tho' the mouth were wide, and the descent perpendicular, the air was cool in the heat of summer; so that the free air, and our bodies that are always immers'd in it, being much warmer in summer than at other times; and the subterranean air, by reason of its remoteness from those causes of alteration, continuing still the same, or but very little chang'd; it's no wonder there should appear a difference, as to sense, when our bodies pass from one to another of them.

And supposing the air of cellars and vaults were really colder in summer than in winter, that is, were discovered to have a greater coldness, not only as to our sense of feeling, but as to weather-glasses; yet need not we have recourse, for the solution of the difficulty, to an *Antiperistasis*, which 'tis much harder to understand, than to find out the cause of the phenomenon; which seems, in short, to be this; that as there are warm exhalations, in all seasons, plentifully sent up by the subterranean heat, from the lower to the superficial parts of the earth; these steams, (which in winter are in a great measure repressed, or checked in their ascent, by the cold frost or snow, that binds the surface of the earth, and choaks up its pores) which being detained in the ground, would temper the native coldness of the earth and water, and consequently that of springs, and of the subterranean air, are by the heat that

that reigns in the outward air, called out at the many pores and chinks, which that heat opens on the surface of the ground, by which means the water of deep springs and wells, and the subterranean air, being deprived of that which is requisite to allay their wonted coldness, are left to disclose a higher degree of it, and seem to have that quality increased, when indeed it is but freed from the mixture of its contrary that weakened it.

As for the heat we find in cellars and vaults in winter, the solutions already given will be applicable to that phenomenon also; which by this way is yet more easy to be accounted for than the other.

But it may be justly questioned, whether cellars, in general, are hotter in the winter than they are in summer. As for the testimony of our senses, upon which alone men usually conclude the affirmative, it may in this case easily deceive us. For those places being sheltered from the winds, and kept from a free communication with the outward air, they will be much less exposed than others to the action of the agents, whatever they are, that produce cold in the air: so that our bodies being constantly immers'd in the air cooled by the winter, and consequently brought nearer to the temper of that air; when those bodies come into cellars, the subterranean air must seem warm to us, tho' in itself it were unvaried as to its temper.

Now that many cellars are indeed colder in the midst of winter, than in the heat of summer, tho' not in respect of our senses, yet in respect of other bodies, which have not the same predispositions, I am induc'd to believe by some experiments I purposely made. Having on a frosty evening hung out in a garden two seal'd weather-glasses, that they might be reduced as near as possible to the temper of the ambient air, I brought one of them into a cellar, and it soon began manifestly to rise, and in two or three hours ascended five or six divisions, whilst the liquor in the other sealed weather-glass, that continued suspended in the same part of the garden, rather a little subsided, than rose; which shews that the air, harbour'd in cellars, is not so powerfully affected by the ordinary efficient of cold, as the free external air. And to shew that the subterranean air, tho' it be less affected by the outward cold, may be somewhat affected by it, instead of growing hotter by *Antiperistasis*; I shall add, that early in the morning, in frosty weather, the liquor in the same weather-glass appeared more subsided, than over night: which shews that the external air lessen'd, not increased, the warmth of the air in the cellar. And having there placed a wide-mouth'd glass of oil, which in thawing weather remained all night fluid as before; the same liquor, the very next night, which proved severely frosty, was so far frozen and congealed, as to sink in other oil, and keep its surface exactly, tho' the glass were turned upside down. And prosecuting my trial, I found, that in a sharp frost, and great snow, the liquor which over-night was beneath the fourth division, a suddain thaw coming with a south wind, the next morn-

PHYSICS.

ing in the same cellar the liquor was ascended to the eighth. And long continuing the weather-glass in the same cellar, to watch its alterations every night and morning, I registred more observations, that confirmed me in my opinion. And after these experiments, meeting with a learned *Polander*, I, without declaring my opinion, enquired of him whether in his country he had at any time observed beer to freeze in cellars in frosty weather; who answered, that in the coldest winters, if the beer were small, the barrels would often be frozen, but not if it were strong. And I have myself observed here in *England*, barrels of beer to be frozen in the cellar in exceeding cold weather; so that one of them being full, and the liquor expanded by freezing, it was forced out at certain chinks, which seem'd to have been made by that expansive force; and the liquor so thrown out, adhered in a considerable lump to the outside of the vessel; yet this cellar had its windows carefully shut, and lay not only near a kitchen, where fire was constantly kept, but had this principal mark of a good cellar, that in the heat of summer it afforded drink sufficiently cool. And enquiring of the physician to the *Russian* emperor, whether their cellars at *Moscow* were really very cold in summer, he answered they were not; that they had distinct cellars for summer and for winter; that their small beer would quickly grow sour in their cellars in summer, if their vessels were not kept in snow; and therefore that their way was to make at the bottom of their summer cellars a deep layer of snow, on which they afterwards cast a convenient quantity of water, whence the whole mass might be turned into a kind of ice. In this snow they keep their casks; making sometimes a layer of snow, and a layer of casks; and digging out their vessels, as they have occasion to use them. From all which it appears how groundlessly 'tis affirmed of cellars, that as they seem to the sense, so they really are hotter in winter than in summer.

But if it should happen, (as possibly it sometimes may) that a vault or cellar is really warmer in summer than in winter; yet I see not why this shou'd drive us to acknowledge an *Antiperistasis*: for neither could the effect be made out by that; nor would there be any necessity to have recourse to it.

For supposing an *Antiperistasis* intelligible, it were improper to alledge it in our case; since to invigorate the warmth of the air by the cold, the air must, according to the peripatetics, be environed with other cold bodies, and the heat retire as far as it can from them; and accordingly 'tis observed, that in winter the deepest cellars are warmest. But in the case before us, the subterranean air, tho' above, it have the cold that reigns in winter; yet beneath, the subterranean heat makes the earth very warm. The learned *Morinus* informs us, that about the year 1615. he visited the mines of *Hungary*, and particularly descended into the deep gold mine at *Cremnitz*; and that after he had descended four-score or a hundred fathom, he found it excessively hot, tho' he had but a slight

flight linen garment on; and tho' he be a maintainer of *Antiperistasis*, yet he affirms, that not only the overseer and workmen of that mine, but also those of several others, unanimously assured him, the lower region of the earth was all the year long very hot, as well in winter as he found it in summer: so that it seems in winter the heat of the subterranean parts, less remote from the superficies, cannot be increased by the coldness of the more internal parts of the earth, those parts being themselves constantly hot.

Indeed he says, that he found the supreme region of the earth, as he calls it, which is that next the air, exceedingly cold, both as he went down into the mine, and as he came up again; and this he ascribes to *Antiperistasis*. But he also relates, that 'twas in *July*, and in very hot weather, that he went down into the mine, and that he exchanged his clothes for a light loose linen garment, such as the diggers wore; and this himself mentions, as that which much increased the coldness he felt: so that if besides this we consider, that he descended into a cooler place, his body being already affected with the great heat, which as he elsewhere takes notice, the season had given the outward air; and being perhaps much heated by riding or walking to the mine; no wonder he found the change very sensible as he went down. And 'tis the less surprizing, that he found the upper region of the earth, as he calls it, more cold when he came up again: since besides the toil of going down, and ascending thro' narrow, low, and difficult passages, he came out of a place so excessively hot, that he tells us, the overseer of the mine would not go back with him the same way he came, but took a far shorter, tho' a more dangerous way, causing himself to be drawn up in a perpendicular groove; because he said, 'twas very unhealthy, coming out of a place where the diggers work naked, and where they even melt in sweat, to make any long stay in the upper region of the earth. So that this author, altho' he maintains *Antiperistasis*, yet allows the upper region to be hot in winter, as well as cold in summer; and consequently that in winter it has not a cold region beneath, as well as above it. But besides this, the matter of fact seems very favourable to my opinion; for I may justly refer the cold he felt near the surface of the earth, to the deception of his sense; but the heat he felt within the bowels of the earth, cannot be referred to the same cause: since he tells us, that at the top of the great and perpendicular groove, by which the mine-master was drawn up, there ascended a large smoak, that, even above the mouth of it, felt actually hot. And besides his own confession, that the deep parts of the mine were more than seemingly hot, I can draw further proofs from these two circumstances, that I have elsewhere met with in his narrative: the one, that on the surface of the earth, it was then excessively hot; another, that the smoak, which, notwithstanding this heat appeared hot, had in its ascent passed thro' four or five hundred feet
of

PHYSICS.

of a cold region of the earth, whereby it may well be supposed to have been much infrigidated. To these relations of *Morinus*, we may add, the arch-bishop of *Upsal* affirms, that going in the year 1528 to visit those deep mountains (as he terms them) in *Poland*, whence they dig solid salt; and having descended fifty ladders, he found in the deeper places, that the workmen were naked, because of the heat; so that supposing the time of the year not to be considerable in this case, it seems from hence, that, provided a man descends low enough into the bowels of the earth, he will find it very hot, even in places that want those metals, or marcasites, or other like mineral substances, by the action of saline liquors, or exhalations upon which, 'tis probable, the heat observed in mines may be produced.

I have hitherto shewn, that the heat of cellars and vaults in winter, has been very improperly ascrib'd to *Antiperistasis*. It has also been unnecessarily ascribed thereto. For as the air of those places is protected from the greatest part of the adventitious coldness that reigns in the outward air; so the subterranean air has a positive cause of heat in winter, that it has not in summer. For, as we formerly observ'd, in summer the pores of the earth being dilated by heat, the warm exhalations, that used to mix with moist vapours in the bowels of the earth, are call'd out, and exhal'd; but in winter, the surface of the earth being hardned by frost, or its pores clog'd, the hot steams, that, as we lately saw, continually, and in plenty ascend from the warm region, or lower parts of the earth, are in great part detained and imprisoned in cellars, and other subterranean cavities, where consequently they produce such a heat as to those who come out of the cold air, may be very sensible. And this the rather, because whilst men, by the coldness of the season, are more than ordinarily careful to stop up the passages, at which the external air may get in, they at the same time stop up the vents, at which the subterraneous exhalations might get out. And a very grave author having occasion to mention cellars, relates it, as a practice in several houses of a town where he had been, to keep vents in their deep cellars, which, in the summer, were opened from time to time, to keep the places sweet and wholesom, and also to let out the warm exhalations, that would otherwise flat and deaden their liquors. And these steams were affirm'd to have been several times observed to ascend visibly into the free air, like smoak: which, several phenomena, and particularly what is said of the hot fumes, that manifestly ascended out of the great groove in the *Hungarian* mine, may render credible.

We come now to consider that phenomenon, which is much urg'd in favour of *Antiperistasis*, the smoaking of water, drawn in frosty weather, out of deep wells and springs.

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But surely 'tis very improperly that some urge for *Antiperistasis*, such examples as the strange spring near the temple of *Jupiter Ammon*, which *Lucretius* and others observed to have been exceeding cold in the day time, and as hot at night; for, not now to examine, whether the story be fabulous, or might not be ascribed to some crafty trick of the priests, who design'd to impose upon *Alexander*, as well as others, and procure an admiration of the place; in this, and other the like cases, for instance, the springs in the islands of *Maldivia*, mention'd by *Pyrad*, must be referred to the peculiar nature of the spring, or some other hidden cause; since if the water of them were but ordinary, and the phenomena the effects of *Antiperistasis*, it might justly be expected, that the like should happen in all springs; which is contrary to common experience.

'Tis related, that in, or near the little *Danish* island *Hueena*, where the famous *Tycho* built his *Urani-Burgum*, there is a spring among many ordinary ones, that, even in the coldest winter, is never frozen; which, in these regions, happens exceeding rarely. *Olaus Magnus* also relates, that in another part of the king of *Denmark's* dominions, viz. *Nidrosia*, one of the chief cities of *Norway*, there is a lake that never freezes. And the learned *Josephus Acosta* tells us, that, among a very great number of hot springs to be met with in *Peru*, "there is a course of water, "at the baths, which they call the baths of *Ingua*, which comes "out all hot and boiling, and that joining to it, there is another, "whose water is as cold as ice. "He adds" that the *Peruvian* emperor, "was accustomed to temper the one with the other; and that it is "wonderful to see springs of such contrary qualities, so near one to another." Hence it should seem, that springs may obtain very peculiar and strange qualities from the nature of the places through which they pass, or from other causes. And who knows what interest such causes as we are strangers to, may have in some phenomena, that are wholly ascrib'd to the heat and cold of the superficial part of the ground; and what effect they have upon many other springs, some of which that are very deep, rise, perhaps, from the warm region of the earth, and are there affected by the place; as both these and others may be by unknown mineral juices and steams; tho' we well know, that some of them, which are saline, without being at all sensibly hot, will powerfully resist congelation?

But the smoaking of waters drawn from deep places in frosty weather, does not necessarily infer such water to be warmer in winter; since that effect may proceed not from the greater warmth of the water, in such weather, but from the greater coldness of the air. For a man's breath in summer, or in mild winter weather, becomes very visible; the cold ambient air suddenly condensing the fuliginous steams, discharged by the lungs; tho' in warmer weather, they are readily diffused in imperceptible particles through the air. And I have observed upon the opening of issues in some mens arms, that tho' no smoak be visible in summer, it will be very conspicuous in exceeding sharp weather,

PHYSICS.

weather, tho' the arms seem to have less heat in frosty weather, than in summer; since in the former season, they are manifestly more slender, the fleshy parts and juices being condensed by the coldness of the air. And tho' the insensible transpirations, continually made from all the parts of our bodies, are not visible here, even in winter; yet in extremely cold countries, as *Nova Zembla*, or *Charleton* island, those effluvia have been observed, not only to be thickned, but to be turned into ice it self, sometimes within-side the sailors shoes. And here in *England*, having lately employed a labourer to dig a deep pit in very frosty weather, two servants of mine, who stood by to see him work, assured me, when they returned, that the steams of his heated body were frozen upon the outside of his waistcoat.

And seeing how fast the water in ponds and ditches, wastes in summer, there is no cause to doubt, that it then continually exhales away more plentifully, than in winter; nay, in the summer, we often see, in the mornings or evenings, the face of the water covered with a mist or smoak, that rises out of it. And I have sometimes observed this aggregate of exhalations to hover over the water, and make, as it were, another river of a lighter liquor, that conform'd it self, for a considerable way, to the breadth and winding of the stream whence it proceeded. And I think it will be easily granted, that the water in summer time is, at least, as warm at noon, when such exhalations are not visible, as in the morning when they are, tho' the air be colder at this part of the day, than at that; which observation gives us the true reason of the phenomenon.

And tho' notwithstanding all this, it were made to appear, that, in some cases, the smoaking water of springs, may be really warmer in winter than in summer; yet a sufficient reason of the phenomenon appears from what I have already delivered about the detention of the warm subterranean vapours by the frost, snow, and rain, that render the earth less perspirable in winter.

That there arise large warm steams from the lower parts of the earth may be proved, not only by what is already mentioned of the *Hungarian* mines, but by the common complaint of diggers in most deep ones, who say they are often troubled, and sometimes endangered by sudden damps, which frequently so stuff up and thicken the subterranean air, as to make it not only unfit for respiration, but able to extinguish their lamps and candles. And I have visited mines, where inquiring of the diggers, whether those hot exhalations that compose their damps, did not sometimes actually take fire within the bowels of the earth, they answered, that in some of their pits, and particularly in one they shew'd me, they did; when, the exhalation suddenly kindling, would make a report at the mouth of the pit like a musquet; and that the flame would actually burn off the hair, and scorch the skins of those workmen, who did not seasonably get out of the pit, when the exhalation appeared to be near kindling; or did not suddenly fall down flat with their

their faces to the ground, till the flame was extinguished. And one of these workmen affirmed himself to have been several times so burned, and even twice in one day. And it seems to me, as well as to *Morinus*, very probable, that those great quantities of rain, snow, and storms, and, perhaps, some other meteors, taken notice of in winter, may rather consist of these subterranean steams, than the vapours and exhalations attracted by the sun. For the sun's heat is then very languid, and acts upon the ground only during the day time, which is very short; whereas those meteors are generated indifferently at all hours of the day and night; and the sky is often, for many days together, quite overcast with clouds, and the surface of the ground so bound up that it will sometimes freeze, even in the sun-shine: whence 'tis not by much so likely, that the heat of the sun, in the midst of all these disadvantages, should elevate so great a plenty of exhalations and vapours, as is requisite to compose the rain, snow and storms, which sometimes last almost all the winter, as that they should be supplied by subterranean steams, plentifully sent up by the heat that continually reigns in the lower parts of the earth, and by traversing the sea, and at other vents, get up into the air.

And agreeably to this doctrine *Morinus* was told, by the masters of the mines in *Hungary*, which are as deep as any I have seen or read of, that the miners were able, certainly, to foretel, sooner than any other men, the tempests and sudden alterations that were to happen in the air, from finding their lights burn blue, and from other manifest signs, in their grooves, of a large tempestuous damp ascending from the lower parts of the earth, tho' the sky above were clear, and the air calm. And an ingenious physician, who lived many years in *Cornwall*, told me, that many experienced fisher-men assured him they often perceived fires shining in the night, sometimes in one place, sometimes in another, which were supposed to be kindled by the sulphureous and other subterraneous exhalations; and that, when they saw those fires, especially if any number appeared in several places; even such as were well acquainted with the coast, would not continue long out at sea, but rather quit an opportunity of catching fish, than not make haste to shore; having often observed, that bold and unexperienced mariners, by sighting these signs, were, in a few hours, caught in a tempest.

And some years since, upon the *Irish* coast, near a strong fortress, called *Duncannon*, where many of his majesties ships lying at anchor, no danger from the wind being apprehended, there seemed suddenly to ascend out of the water, not far from them, a black cloud, in shape and bigness like a barrel, which mounting upwards, was soon followed, as the most experienced pilot foretold, with so hideous a storm, as forced those ships to put again to sea. And this account was both written by the principal officers of the Squadron, to their superiors in *England*, and given soon after it happened, by the chief of those eye-witnesses, and particularly

PHYSICS.

cularly by the pilot, to a very near kinsman of mine, who commanded the land forces in that country.

'Tis also said, that not far from the city of *Buda*, there is a hot spring, called purgatory, which the waters of the *Danube* it self are not able to keep cool; nay, within the very banks, betwixt which that great river runs, there boil up springs, which in their lower parts are intolerably hot. And having heard of a ditch in the north of *England*, whence not only subterranean steams, but those so sulphureous as to be easily inflammable, constantly and plentifully ascended into the air, I inquired about it of the minister of the place, who was well versed in mines; and he attested the truth of the relation upon his own knowledge. It was also confirmed to me by a very ingenious gentleman, who went purposely to visit this place, and found it true, that a lighted candle, being held where the exhalation issued out, would give fire thereto, and make it actually flame for a considerable time. And as this place was but lately taken notice of, there may probably be very many others, yet undiscovered, that supply the air with store of mineral exhalations, proper to generate fiery meteors and winds. A great searcher after mines told me, 'tis very usual, in some places, where he is concerned in that affair, to see certain great fires moving in the air, which the diggers call dragons. And the *Russian* emperor's physician inform'd me, he had observed, in winter, a river in *Muscovy*, where, tho' the rest of the surface was frozen, there was a part of it near a mile long, that remain'd uncovered with ice, which, probably, was kept from being generated by those subterraneous exhalations; since, he says, he saw them ascend up all the way like the smoke of an oven. And in case the matter of fact delivered by *Olaus Magnus* be true, concerning the strange thaws that sometimes happen, with a terrible noise, in the great lake *Veter*, those wonderful phenomena may not, improbably, be ascribed to the large ascent of hot subterranean steams, which suddenly cracking thick and solid ice, in many places at once, produce the hideous sounds, and the hasty thaw he speaks of. And this suspicion may be countenanced from hence, that before these sudden thaws, the lake begins, with great noise, to boil at the bottom; and also from what is related by a more authentic writer, the Jesuit *Martinus*, who declares, that at *Pekin*, the capital of *China*, 'tis very usual, after the rivers and ponds have continued hard frozen over, during the winter, for the thaw to be made in one day; which, since the freezing of the waters, as he tells us, required many, makes it very probable, that the sudden thaw is effected, as he also inclines to think, by subterranean steams; which may well be supposed exceeding large, and to diffuse themselves every way to a very great extent, since they are able so soon to thaw the rivers and ponds of a large territory: and, which makes greatly for our purpose, they begin, contrary to vulgar thaws, from the bottom upwards.

Since then the lower parts of the earth, send up great plenty of exhalations and vapours to the upper, 'tis obvious, that as in several places these

these steams get into the air, either thro' vents, or by growing strong enough to force themselves a passage; so in most others, where the ascending steams find no commodious vents, or are too faintly driven up to force themselves a passage, they must be repress'd or detained below the surface of the earth, which has its pores in winter usually block'd up with snow or rain, or its surface constringed and hardned with ice or frost; so that these exhalations being pent in, and continually receiving fresh supplies from beneath, 'tis no wonder, if they should warm deep cellars and wells, where they are thus detained: and therefore our husbandmen speak rationally, when they say, that the snow keeps the ground warm. Dr. Smith, the learned *English* ambassador to *Moscow*, makes it to be one of the principal reasons of the great fertility of the country thereabout, that, during almost all the winter, [the ground is to a great height covered with snow; which not only enriches it by the fertilizing salt the earth gains from the snow, when that comes to be melted; but also contributes to its improvement, by obstructing the pores, at which the nitro-sulphureous, and other useful corpuscles, that are sent up by the subterranean heat, would easily get away. And the *Russian* emperor's physician has assured me, that about *Moscow*, where the surface of the ground is far more bound up in winter, than 'tis in these parts; and where they keep their cellars much closer; the subterraneous exhalations being hinder'd from flying abroad, will, in time, multiply so fast, that upon the unwary opening of their doors, which have been long kept shut, there would fall out a very thick warm smoak, which has sometimes brought men into danger of suffocation.

I must not, however, conceal an experiment or two I have met with, which seem to shew, that subterranean places are really hotter in winter, than in summer.

The learned jesuit *Zucchius*, assures us, that having kept a good seal'd weather-glass, for three years together, in a cellar, he found the water to rise by the coldness of the ambient air in the summer, and to be depressed by the rarification of it in the winter; which seems undeniably to prove, that whatever be the reason of it, the heat in subterranean places is indeed greater in winter than in summer. And another jesuit affirms, he found by a weather-glass, that a well at the place where he lived, was colder in summer, and hotter in winter.

'Tis not, however, universally true, that cellars, and other subterranean places, are hotter in winter than in summer. For my own observations, made in a cellar, with a sealed weather-glass, manifest the contrary. I would, therefore, make a distinction of subterranean places; for some are deep, as the best sort of cellars; others deeper yet, as the *Hungarian* mines, mentioned by *Morinus*; and some again are but shallow, as many ordinary cellars and vaults: of these three sorts of subterranean places, the deepest of all do not seem to grow hot and cold, according to the several seasons of the year, as the vulgar doctrine of antiperistasis requires; but are, according to some mineralists, continually hot: the shallower

shallower sort of subterranean places, being fenced from the outward air, are not so subject to the alterations of it, as open places; yet, by reason of their vicinity to the surface of the earth, they are so far affected with the mutations, whereto the outward air is liable, in several seasons of the year, that in winter, though they be warm in respect of the colder air abroad, yet they are really, as far as I have try'd, colder in very cold weather, and less cold in warm weather. Thus the *Polonian* nobleman, formerly mentioned, assured me, that, in his country, sharp winters would freeze small beer in cellars, that were not very deep, tho' it continued fluid in those that were. And the anonymous jesuit lately mentioned, acknowledges, he found but little difference between the temperature of the water in the well he examined in summer, and in winter, tho' it were a considerably deep one; and adds, that at *Florence*, where the subterranean vaults are shallower, the air is observ'd to be colder in winter than in summer; tho' the contrary has been found in the deep cellars at *Rome*. So that the lowest sort of subterranean cavities being, for ought appears, perpetually hot; and the upper or shallower sort of them, being colder, not hotter in cold weather than in warm; 'tis about the temperature of the middle sorts of them, such are the deeper and better cellars, that the question remains to be determined.

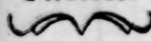
We must next consider, that 'tis not so easie a matter as philosophers think, to make, with the weather-glasses hitherto in use, an experiment to our present purpose, that shall not be liable to some exception, especially if the cellar, or well, be very deep. For the gravity of that thick and vapid subterranean air, and the greater pressure which the air may there have, by pressing in an atmospherical pillar, lengthened by the depth of the cellar, may, in very deep cavities, as well alter the height of the water in common weather-glasses, as heat and cold; and so make it uncertain, when the mutation is to be ascribed to the one, and when to the other; or at least very difficult to determine distinctly, what share is due to the pressure, and what to the temperature of the air. And this uncertainty is much increased, by considering, that not only in places where the heights of the atmospherical cylinders differ, the pressure of the air upon the stagnant water in the weather-glasses may do so too; but even in the same place the instrument remaining unmoved, the pressure of the atmosphere may, as I have often observed, soon alter considerably, and that without any constant and manifest cause; so that an erroneous estimate of the temperature of the air, can scarce possibly be avoided, without the help of a sealed weather-glass, where the included liquor is subject to be affected by heat and cold, and not pressure of the air. To apply this to *Zucchini's* his experiment; unless he made his observations with the assistance of a sealed weather-glass, it may be suspected, that he might accidentally find the water in a common one, (which he appears to have us'd, as, probably, knowing no other,) to be higher, when he look'd on it

it in summer, than in winter; not because really the subterranean air was colder in the former season, than in the latter; but because the atmosphere chanced then to be heavier. And considering in how few hours, I have sometimes observed the quick-silver, both in a good barometer, and even in an unseal'd weather-glass furnished with quick-silver, to rise almost an inch perpendicularly, without any manifest cause proceeding from cold; I cannot think it impossible, that in long weather-glasses, furnished only with water, or some such liquor, the undiscerned alterations of the atmosphere's pressure, may produce very notable ones in the height of the water in such instruments. But farther, *Zucchini* having, for ought appears, made his observations only in one place, we are not sure, that it was not one of those whereon subterranean exhalations have a peculiar and considerable effect; as happens in the great and sudden thaws, that sometimes begin from the bottom, and thereby argue their being produc'd by steams, ascending from the lower parts of the terrestrial globe; which may be farther confirm'd by what was formerly noted of the sudden damps happening in mines. But what is of the most importance, the learned *Maignan* had the same curiosity as *Zucchini*, but with very different success; and, therefore, this inquisitive person rejects the vulgar doctrine of antiperistasis, upon account of two experiments. For, first, he says, he found with a thermometer, that when, in winter, a cold northerly wind froze the water without doors, it was no less cold in wine-cellars, than in the same season, and at the same hour of the day in his study; only the paper-shuts of his window, that regarded likewise the north, being put to. And these cellars too, it seems, were of the very best of the kind, wherein the greatest cold was felt in summer. But his next experiment is yet more considerable. "I found," says he, "with a very exact thermometer, that the greatest coldness of some excellent wine-vaults, in the most vehement heat of the summer, was not equal to that they had in the winter; tho' the former seem'd much the most severe to sense."

Thus far our learned author, who, seeming by the mathematical part of his *Perspectiva Horaria*, to be an accurate and industrious observer, we may oppose his experiment to that of *Zucchini*, which it flatly contradicts; and, therefore, since the depth of the cellar is of great moment in experiments of this nature; since also the particular parts of the place or soil, where the cellars, or other cavities, happen, may, in some cases, deserve to be consider'd; and since, lastly, neither *Zucchini*, or *Maignan*, seem to have been aware of the differing weights of the atmosphere in the same place; I shall determine nothing positively, till the experiment has been carefully made, for a competent space of time, in several places, and that not with common weather-glasses, but with sealed thermometers.

Having thus shewn, that tho' experience be so confidently appeal'd to, by the maintainers of antiperistasis, yet nothing considerable to

favour

PHYSICS.  favour their cause, has been hitherto drawn from thence; I shall next shew, that it bears witness against them.

I took an iron rod, about the bigness of a man's finger, having at one end of it a very broad and thick piece of iron, shaped almost like a spatula, that the quantity of the matter might, upon the ignition of the iron, make the heat very considerable: then causing this thick end to be made red hot in the fire, and having suddenly quench'd it in cold water, I could not perceive, that the other end of the rod, by which it was held, grew at all sensibly hot, as a favourer of antiperistasis would have expected it should do, to a very high degree; as presuming, that the innumerable particles of heat, which swarmed in the compact body of the red hot part of the iron, must, to fly the cold of the water, retire in throngs towards the other extreme of the iron, and make it exceedingly hot. And lest any pre-existent warmth should hinder me from perceiving an increase of heat, in case any were produced in the handle of the iron, I caus'd it, the next time the trial was made, to be kept in cold water; yet even then the immersion of the broad ignited end in the cold water, brought as little sensible heat to the other end, as it had done before: and having caus'd the experiment to be made by another, it succeeded with him, as it had done with me.

Again; I took an excellent seal'd weather-glass, fourteen inches long, furnished with good spirit of wine, and having provided an open mouth'd glass, of a convenient shape and size, and fill'd it to a due height with common water, I so ordered the matter, that the stem of the thermometer being supported by the cork, into which, by a perforation, it was inserted, when the glass was stopp'd by the cork, the whole ball of the thermometer was immers'd in the water, that fill'd the wide-mouth'd glass, and no where touched, either the bottom or the sides of the glass, so that the ball was every way surrounded with water. The instrument being thus prepar'd, we observ'd at what station the surrounding cold water had made the tinged spirit rest in the thermometer; and then having provided a fit proportion of warm water, in a proper vessel, I remov'd the instrument into it, and plac'd it so, that the liquor reach'd to a convenient height on the outside of the open mouth'd glass: but tho' I carefully watch'd, whether the heat of the external water, would increase or strike inwards the cold of that water, which immediately encompassed the ball of the weather-glass; yet I perceived no such matter, the tinged spirit in the stem keeping its station, till the heat having, by degrees, been diffus'd thro' the cold water, by the intervention of that, now warmed, the tinged spirit in the thermometer began to ascend.

And to reduce the other part too, of the doctrine of antiperistasis, to the determination of an experiment, the same thermometer was plac'd in the same wide-mouth'd glass, just after the former manner, only instead of the cold water, that which immediately surrounded the
glass

Experiments and Observations upon Cold.

711

PHYSICS.

glass was warm; and when the warmth had impell'd up the spirit, till its ascent began to be very slow, I immers'd the instrument to a convenient depth in a vessel, that contain'd some very cold water, mixed with several pieces of ice. But it did not appear to me, that the heat of the water, which immediately encompassed the ball of the weather-glass, was at all increas'd, by that liquors being surrounded with water exceeding cold; for the languid motion of the spirit upwards, was not hereby so much as sensibly accelerated, but rather the ascent was, by the chilness of the contiguous water, quickly check'd, and the ascending spirit soon brought to subside again. And for fuller satisfaction in the phenomena of this, and the former experiment, I observed them more than once.

XXVI.

Mr. *Hobbs's* theory of cold, appears so inconsiderately chosen, and so slightly made out, that I should not think it deserved a particular examination, but for the grand air wherewith it is proposed. For he talks so much of demonstrations, and sets himself so far above the most eminent writers, that the unwary may mistake his confidence for evidence; and rather accuse their own understanding, than distrust his doctrine.

*Mr. Hobbs's
doctrine of cold
examined.*

Mr. *Hobbs's* doctrine, so far as relates to cold, is in substance this. The motion of the sun between the tropics, driving the air towards that part of the earth's surface, which is perpendicular under it, makes it spread it self every way; and the velocity of this expansion of the air, grows gradually greater, as its circles parallel to the *Aequator* become less. Wherefore this expansive motion of the air, drives before it such of its parts, as are in its way continually towards the poles more strongly, as its force comes to be more united; that is, as the circles parallel to the *Aequator* are less, or the nearer it comes to the poles of the earth. In those places, therefore, which are nearer to the poles, there is a greater cold, than in those which are more remote from them. Now this expansion of the air upon the superficies of the earth, from east to west, by reason of the sun's perpetual arrival to the places which are successively under it, makes it cold at the time of the sun's rising and setting; but as the sun comes to be more perpendicular to those cooled places, so by the heat, which is generated by the supervening simple motion of the sun, that cold is again remitted, and can never be great; because the action, by which it was generated, was not permanent. This, therefore, is a possible cause of cold in those places, that are near the pole, or where the obliquity of the sun is great.

Water may be congealed by cold, from the action of the air in those parallels will rake the superficies of the earth; and that with a motion so much the stronger, as the parallel circles towards the poles grow less. From whence must arise a wind, which will force together the upper

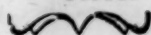
PHYSICS. upper parts of the water, and withal raise them a little, weakning their endeavour towards the center of the earth. And from their endeavour towards the center of the earth, joyned with the endeavour of the said wind, the upper parts of the water will be pressed together and coagulated; that is to say, the top of the water will be skinned over and hardened; and so again the water next the top, will be hardened in the same manner, till at length the ice be thick. And this ice being now compacted of little hard bodies, must also contain many particles of air received into it. And as rivers and seas, so, in the like manner, may the clouds be frozen. For when, by the ascending and descending of several clouds at the same time, the air intercepted between them, is, by compression, forced out, it rakes, and, by degrees, hardens them. And tho' those small drops, which usually make clouds, be not yet united into greater bodies, yet the same wind will be made; and by it, as water is congeal'd into ice, so will vapours in the same manner be congeal'd into snow. From the same cause it is, that ice may be made by art, and that not far from the fire; which is done by mixing snow and salt together, and by burying it in a small vessel full of water: for, when the snow and salt, which contain a great deal of air, are melting, the air which is pressed out every way in wind, rakes the sides of the vessel; and as the wind by its motion rakes the vessel, so the vessel, by the same motion and action, congeals the water within it.

We find by experience, that cold is always more remiss in places where it rains, and, *ceteris paribus*, where the weather is cloudy, than where the air is clear. For, in clear weather, the course of the wind, which raked the superficies of the earth, as it is free from all interruption, so also it is very strong. But when small drops of water are either rising or falling, that wind is repell'd, broken, and dissipated by them; and the less the wind is, the less is the cold.

We find, also, by experience, that in deep wells the water freezeth not so much, as upon the superficies of the earth. For the wind, by which ice is made, entring into the earth, loseth some of its force, tho' not much; so that if the well be not deep, it will freeze; but if it be so deep, that the wind, which causeth cold, cannot reach it, 'twill not freeze.

We find, moreover, by experience, that ice is lighter than water; the cause whereof is manifest from hence, that the air is received in, and mixed with the particles of the water, in the act of congelation.

To examine this theory, we may, in the first place, observe, that Mr. *Hobbs's* notion of cold, is not accurately delivered. It may be well question'd, whether the external tendency of the spirits and fluid parts of the bodies of animals, necessarily proceeds from, and argues heat; since in our pneumatical engine, when the air is withdrawn from about an included viper, there is a great intumescence, and, consequently, a greater endeavour of the fluid parts of the body outwards, than we see



see made by any degree of heat in the ambient air, usually produced by the sun. But Mr. *Hobbs* tells us, that to cool, is to make the external parts of the body endeavour inwards; yet our experiments tell us, that when a very high degree of cold is introduced, not only into water, but into wine, and other liquors, there is a plain swelling, and, consequently, an endeavour outwards of the parts of the body cooled. And, certainly, cold having an operation upon a great multitude and variety of bodies, as well as upon our organs; he that would give a satisfactory definition of it, must take into consideration several other effects, besides those it produces on human bodies. And even in these, he will not easily prove, that, in every case, any such endeavour inwards from the ambient ætherial substance, as his doctrine seems to suppose, is necessary to the perception of cold: since as the mind perceives several other qualities, by various motions in the nervous or membranous parts of the organ; so cold may be perceived, either by the decrease of the agitation of the parts of the object, with regard to those of the organ; or else by a different impulse of the sensitive parts, occasioned by some change made in the motion of the blood or spirits, upon the decay of that motion; or by the turbulent velocity of those excrementitious steams, which, when the blood circulates as quick, and the pores are kept as open as before, are dissipated by insensible transpiration.

'Tis a known thing, that many hysterical patients complain of a great coldness in their head, or other parts, and sometimes too when they seem to be otherwise hot. And I know a nobleman, who falling, as frequently he has done, into a fit of the stone, feels an universal coldness over his whole body, like that which begins the fit of an ague. And tho' he assures me, that the stones, which he usually voids, are but very small; yet, whilst the fit continues, he cannot, by cloaths, or almost any other means, keep himself warm.

Hence it appears, there may be other ways, besides those already mentioned, of perceiving cold, tho' the outward parts of our bodies are not prest inwards. Mr. *Hobbs* declares, that he who would know the cause of cold, must find by what motion the external parts of a body endeavour to retire inwards; but this seems an inconsiderable direction. For, in compressions that are made by surrounding bodies, there is produced an endeavour inward of the parts of the compressed body, tho' not cold, but sometimes heat be thereby generated. And, I hope, Mr. *Hobbs* will not object, that in this case the parts do not retire, but are thrust inwards; since, according to him, no body at all can be moved, but by another contiguous and moved. And this may suffice to shew, that the notion of cold, in general, is not so easie to acquire as many think; and therefore it needs be no wonder, that it hath not been accurately proposed by Mr. *Hobbs*. In the next place, the cause he assigns, why a man can blow hot or cold with the same breath, is very questionable; because he supposes in part of the breath

PHYSICS.

such a simple motion, as he calls it, of the small particles of the same breath, as he will not easily prove; and because that without the suspected supposition, I could give a more probable account of the phenomenon, if I had not some scruples about the matter of fact itself: for tho' I am not sure, that farther trials may shew the wind or breath, blown out at the middle of the compressed lips, to have in it such a real coldness, as men generally ascribe to it; yet hitherto some trials incline me to suspect, that in estimating the temper of the wind produc'd, our senses may impose upon us. For having taken a very tender seal'd weather-glass, and blown upon it thro' a long, slender glass-pipe, to be sure that my breath should issue out in a small stream; by this wind beating upon the ball of the weather-glass, I could not make the included spirit of wine subside; but it manifestly ascended, tho' the wind, that I presently blew thro' the same pipe, seem'd sensibly cold, both to the hand of by-standers, and to my own, which was at that time, more than ordinarily cold. But whatever be the cause of the effect, there are several things that make Mr. *Hobbs's* hypothesis of cold unsatisfactory. For the grand cause he assigns of cold, and its effects, is wind; which, according to him, is air mov'd in a considerable quantity, and that either forwards only, or in an undulating motion: and he tells us too, that when the breath is more strongly blown out of the mouth, then the direct motion is prevalent (over the simple motion) which, according to him, makes us feel cold; for, says he, the direct motion of the breath or air is wind, and all wind cools or diminishes former heat. He adds, that not only great, but almost any ventilation, and stirring of the air, refrigerates. But,

1. There are very hard frosts, not only continued, but often begun, when the air is calm and free from winds: and high and boisterous southerly winds are not here found to be near so cold, as far weaker winds that blow from the north-east.

2. If Mr. *Hobbs* teaches, 'tis the direct motion of the stream of breath, if more strongly blown out, that makes us feel cold, he is obliged to assign a reason, why in an æolopile with a long neck, the stream that issues out, tho' often far stronger than that, which is made by compressing the lips, at a considerable distance from the orifice it issues out of, is not cold, but hot.

3. Mr. *Hobbs* else-where teaches, that when in our engine, the pump has been long employ'd to exhaust the receiver, there must be a vehement wind produc'd in that receiver; yet by one of our experiments it appears, that for all this, in a good seal'd weather-glass plac'd there, before the included air began to be emptied, there was no sign of any intense degree of cold produc'd by this suppos'd wind; so that either the wind is but imaginary, or else Mr. *Hobbs* ascribes to winds, a power of cooling, that does not belong to them.

4. We find by experience, that in hard frosts water will freeze, not only tho' there be no wind stirring in the ambient air, but tho' the liquor

liquor be kept in a close room, where, if the wind were high abroad, it could not get admittance. And some experiments carefully made have assur'd us, that water seal'd up in one glass, and that glass suspended in another carefully stop'd, to keep out all adventitious air, may nevertheless be turn'd into ice.

5. We found by other experiments, that a frozen egg, tho' suspended in, and perfectly surrounded with water, where no wind cou'd come at it, wou'd be every way crufted over with ice; in which case there is no probability, that the ice should be generated according to the way propos'd by Mr. *Hobbs*. For he will scarce prove, that a wind pierc'd the shell and closer coats of the egg, to get into the contain'd liquors, and freeze them: and a more unlikely assertion it would be, to pretend, as he who maintains Mr. *Hobbs*'s doctrine must, that so very little air, if there be any, as is mixed with the juices of the egg, can by the cold, which does not expand air, be turn'd into a wind subtil enough, freely to penetrate the shell and coats of the egg, and able to diffuse itself every way, and turn, on every side, the neighbouring water into ice; and all this, tho' it appears not, by bubbles breaking thro' the water, that any adventitious air comes out of the egg at all: and supposing some such were contain'd in the egg, yet what shadow of reason is there to conceive, that the air which was engaged in, and surrounded with the substances of the white, and the yolk of the egg, must needs be a wind; since, according to Mr. *Hobbs*, wind requires a considerable motion of most of the parts of the air mov'd the same way; and according to him also a body cannot be put in motion, but by another body contiguous and mov'd?

6. Mr. *Hobbs*, indeed, affirms that all wind cools, but is so far from proving that the highest degrees of cold must needs proceed from wind, that he does not shew all winds to be cool. Nor are we bound to believe it without proof; since wind being, according to him, but air mov'd in a considerable quantity, either in a direct or undulating motion, it does not appear how motion should, rather than rest, make air grow cold. For tho' it be true, that winds usually seem cold to us, yet it is not universally true; since some, who have travelled into hot countries, and particularly the learned *Alpinus*, complains, that the winds coming to them in the summer from more torrid regions, have appear'd to be almost like the steam that issues out at the mouth of a heated oven. And 'tis said, that the southern winds near *Ormus*, have been sometimes so hot, as at once to destroy an army. But even when the wind does feel cold to us, it may often do so but by accident; for the steams that issue out of our bodies being usually warmer than the ambient air; and the more inward parts of our bodies themselves, being very much hotter than it; the same causes that turn air into wind, put it into a motion, that both displaces the more neighbouring and more heated air, and also makes it pierce far deeper into the pores of the skin; whereby becoming sensible to

PHYSICS.

those parts, that are somewhat more internal than the *Cuticula*, and far more hot; the air turn'd into wind seems to us more cold, than the stagnant air. Thus, tho' air blown thro' a pair of bellows upon one's hand, when 'tis in a moderate temper, will seem very cold; yet, that the ambient air is thus turn'd into wind, without acquiring such a cold as is presum'd, may appear by blowing the same air, with the same bellows, upon weather-glasses; for in doing this, we could not observe, that the wind beating upon them did sensibly cool either the air, or the liquor. Tho' 'tis not impossible, that in some cases the wind may cool even inanimate bodies, by driving away a parcel of ambient air, impregnated with exhalations less cold, than the air that composes the wind. But this is no more than would be effected, if, without a wind, some other body should precipitate out of the air, near the weather-glass, the warmer effluvia; especially if the precipitating body introduce, in the room of the displaced particles, such as may be justly term'd frigidific.

7. Nor can we admit, without a favourable construction, Mr. *Hobbs's* expression, that all wind cools or diminishes former heat. For if we take heat in the most common acceptation; to make wind the adequate cause of cold, it must in many cases do more than diminish former heat. Water, for instance, ready to freeze, is already actually cold in a high degree; yet the wind, according to Mr. *Hobbs*, must make this very cold liquor, still more cold, before it can turn into ice.

The remaining part of Mr. *Hobbs's* theory of cold, may now be soon dispatch'd, the greatest part of it being to shew, that there is an expansion of the air, or a wind generated by the motion and action of the sun: but why this wind thus generated must produce cold, I do not see that he proves; nor does his affirming, that it moves towards the poles, help the matter. For we have shewn, that wind is not sufficient to produce far less degrees of cold, than those felt in many northern regions; and there must be some other cause than the motion of the air, or steams driven away by the sun, to make bodies, not in themselves cold, become vehemently so in their passage. For Mr. *Hobbs* cannot, as other naturalists do, derive the coldness of freezing winds from the cold steams they meet, and carry along with them in their passage thro' cold regions; since then those steams, rather than the wind, would be the cause of that vehement coldness; and so it might justly be demanded, whence the coldness of those cold exhalations proceeds. Besides, 'tis very precarious, and contrary to observation, to imagine such a wind, as he talks of, to blow whenever great frosts happen; since, as we noted before, very vehement glaciations may be observ'd, especially in northern regions, when the air is calm and serene.

The account he gives of turning water into ice, is the most unsatisfactory I ever yet met with: in supposing that by the endeavour of the wind to raise the parts of the water, join'd with the endeavour

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your of the parts of the water towards the center of the earth, the upper parts of the water will be prest together, and coagulated, he says that which is very far from satisfactory. For ice is often produced, where no wind can come to beat upon the upper parts of the water, and to raise them: and in vessels hermetically seal'd, which exactly keep out air and wind, ice may be generated, as our experiments demonstrate. And this alone were a sufficient answer, since the whole explanation is built upon the action of the wind. But this is not all, for he should have prov'd, that the upper parts of the water must be raised in congelation; especially since oil, and several other liquors, are contracted by it. And what shew of probability is there, that by the bare endeavour of the wind, and the gravity of the superficial parts of the water, there should be any such forcible compression made, as he takes for granted? Yet this itself is less improbable than, supposing the uppermost parts of the water to be pressed together, that pressure shou'd be sufficient to congeal them into ice. So bold and unlikely an assertion should at least have been countenanced by some plausible reason, or parallel example. For I remember no instance, wherein any degree of compression, that has been employ'd, much less so slight an one as this must be, considering the causes whence 'tis said to proceed, can harden any liquor into ice. By filling a pewter vessel with water, and when 'tis exactly clos'd, compressing it by blows of a hammer, till the water be reduc'd to penetrate the very pewter, we found not that so violent a compression gave the water the least disposition to become a hard body. And as for the way Mr. *Hobbs* advances of increasing the thickness of ice, 'tis very difficult to conceive, how a cake of ice on the top of the water, being hard frozen to the sides of the containing vessel, and thereby separating the included water and the external air, the wind that cannot come to touch the water, because of the interposition of the hard and rigid ice, should yet be able, sometimes at the depth of ten feet, or more, to beat upon the subjacent water, and turn it into ice. And it is yet more difficult to conceive, how the wind must do all this, when, as we lately noted, the water very often gradually freezes downwards, to a great depth, in places where the wind cannot come at all. And as to what Mr. *Hobbs* further teaches, that the ice must contain many particles of the air receiv'd into it, we have formerly shewn, how erroneously he discourses about those icy bubbles.

The reason he assigns of the freezing of water with snow and salt, is as little satisfactory as the rest of his theory. He affirms, without proving it, that snow and salt have in them a great deal of air; and very precariously asserts, that this air must needs be prest out every way in wind, and so rake the sides of the vessel: 'tis strange, that far more diligent observers than Mr. *Hobbs*, should take no notice of any such wind, if any such wind there were. But this is yet less strange than that, this wind must so rake the sides of the vessel,

PHYSICS.

vessel, as to make the vessel by the same motion and action congeal the water within it. For what affinity is there between a wind, passing along the outside of a glass, altogether impervious to it, and the turning a fluid body, included in that glass, into a hard and brittle one? The wind, indeed, may perhaps, if it be strong, a little shake or agitate the particles that compose the glass, and those may communicate some of their motion to the contiguous parts of the water; but why all this must amount to the turning of that water into ice, is more, I confess, by far, than I can apprehend. Tho' you long blow upon a glass of water with a pair of bellows, where there is not an imaginary wind, like Mr. *Hobbs's*, but a real and manifest one; yet the water will be so far from freezing, that it will scarce be cool'd. And if sea-salt contain so much air, by virtue of which, it, as well as the snow, produces so intense a degree of cold; how chance that, being dissolv'd in a little water without snow, it does not produce a considerable degree of cold? Besides, in the experiment we made of freezing water up in seal'd bubbles; tho' the bubbles were suspended in other glasses, whose sides no where touched them, and the remaining part of whose cavities were fill'd, some with air, and some with uncongealable liquors; what likelihood is there, that Mr. *Hobbs's* insensible wind should be able to occasion so many successive rakings thro' different bodies, as there must be, to propagate the congealing motion of the wind, thro' the first glass, to the included air or liquor, and thro' that new medium to the glass immediately containing the water, and thro' that to the innermost parts of the water seal'd up? It might be further objected, if it were worth while, that Mr. *Hobbs* does not so much as offer at a reason, why spirit of wine, *Aqua fortis*, or even brine, if it be of the strongest sort, are not either by this mixture, or (here in *England*) by the wind in the open air, turn'd into ice.

The reason why cold is more remiss in rainy or cloudy weather, than in that which is more clear, seems to be no better assign'd by Mr. *Hobbs*, than by others who have written before him: for I have seen great and lasting frosts in cloudy, and sometimes very dark weather: and what he talks of the wind's being more strong in clear weather, than in cloudy, is of no great importance; since common experience shews, that in clear weather the air may be very cold, and the frost very great, where no wind is felt to rake, as he would have it, the surface of the earth. Nor does experience bear witness to what he rashly pronounces, that the less is the wind, the less the cold. There are but two phenomena more, which Mr. *Hobbs* here pretends to explain: the one is, that in deep wells the water freezes not so much, as upon the surface of the earth. But Mr. *Hobbs* has not rightly assigned this, to the wind's entering more or less into the earth, by reason of the laxity of its parts; since it is very improbable, that the wind should not, as he says it does not, lose much of its force by entering into the earth at its pores, and other lesser cavities, to so
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great a depth as water lies in several wells, subject to freezing: besides, experience teaches us, that wells may be frozen, tho' their mouths be well covered, and the wind thereby kept from approaching near the included water; and very many wells, that are subject to freeze, when northerly and easterly winds reign, will likewise be frozen in very cold winters, whether any winds blow, or not.

The last phenomenon Mr. *Hobbs* attempts to solve, is that of ice being lighter than water. The cause whereof, says he, is manifest from what I have already shewn; namely, that the air is receiv'd in, and mixed with the particles of the water whilst congealing. But that this is not the true reason, may be argued from hence, that if a conveniently shap'd glass-vessel be quite fill'd with water, and expos'd, either unseal'd or seal'd, to congelation, the ice will contain numerous bubbles, which, at least in the seal'd vessel, cannot by Mr. *Hobbs*, (who will not say that glass is pervious to the air) be pretended to proceed from bubbles, that got from without into the water, whilst it was congealing. And we have manifested, by particular experiments purposely made, how little of air there is, even in those bubbles that are generated in ice, made in vessels, where the air was not kept from the water.

Thus we have seen, that most of the particulars advanced in Mr. *Hobbs*'s theory of cold, are either precarious or erroneous; and were they neither, yet the whole would, I fear, prove very insufficient. For this learned author has past by far the greatest part even of the more obvious phenomena of cold, without attempting to explain them, or to shew, so much as in a general way, that he had consider'd them, and thought them explicable by his hypothesis.

XXVII.

I will not undertake to prove the nature of cold to be privative, but think it easy to shew, that the arguments produced for its being positive, are not conclusive. 'Tis said in the first place, that if cold be but a privation, it cannot be the object of sense. To clear this, I must observe something about sensation in general. That then which produces in the mind those perceptions, which we call sensations of outward objects, is the local motion, caused by means of their action, upon the outward organs, in some internal part of the brain, to which the nerves belonging to those organs correspond; and the diversity of sensations may be referr'd to the different modifications of those internal motions of the brain, either according to their greater or less celerity, or other circumstances; as we see in the variety of sounds, some whereof are grave, some sharp, some harmonious and pleasant, some jarring and offensive; yet all of them proceed from the variations of those impulses, which the air, put into motion by sonorous bodies, gives to the

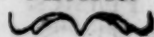
*Whether cold
be a positive,
or privative
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PHYSICS.

the ear. As the air then is differently affected by a very grave sound, and a very acute one; tho' the former proceed from the want of that celerity of motion in its undulations, which is to be found in the latter; whence it approaches the nature of rest; so in the organ of feeling, perception may be produced upon the contact of a cold body, very different from that which is caused by the contact of a hot one: and this, tho' the thing perceived, and by us called coldness, consists but in a less agitation of the parts of the cold body, than of those of the hot one, in respect to our organs of feeling. And since it is manifest, that bodies communicate their motion to those they happen to act upon, and lose of their own by such communication; if a man take a piece of ice in his hand, the agitation of the particles of the organ, will be communicated to the corpuscles of the ice, which, upon that account, quickly begins to thaw; and the contiguous parts of the hand, losing of the motion acquired by the ice, there needs nothing else to lessen the agitation they had before: and no more than this decrease of agitation is required, to occasion in the mind such a new and different perception, as men have tacitly agreed to call coldness.

'Tis farther observable, that the organs may be so accustomed to be affected after a certain manner by those external objects, whose operation on them is very familiar, that the privation, or bare diminution of the wonted operation, leaves their parts in a different disposition from what they were in formerly; which change in the organ will be attended with a perception of it in the mind. Thus, tho' darkness be confessedly a privation of light, and the degrees of it, gradual diminutions of light; yet the perceptive faculty, by means of the eye, may well be said to perceive both light and darkness; that is, both a positive thing, and the privation of it. And it is obvious, that the motion of a shadow, or a gradual privation of light, is plainly, and without difficulty, discoverable by the eye. And to shew, that there is on these occasions an apparent change made in the organ of vision, we need but desire a person in the day-time, to look towards an enlightned window, and then towards an obscure part of the room; since when he does the latter, for want of such a degree of light as before came in at the pupil, that circle will grow manifestly larger. Thus, when a man comes out of the sun-shine, (where the pupil contracts, to shut out an excessive light, which would be offensive to the organ,) into a darkned room; it will be some time before he can clearly see others there, whose pupils have had time to be so enlarged, as to let in light enough to render objects visible to them, which are not so to him, whose pupils are yet contracted by the light they were just before expos'd to.

The next argument to be consider'd is this. When we put our hands into cold running water, in the winter season, the cold we perceive therein cannot be called a mere privation; and there is a great difference



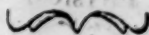
ference between feeling water cold, and the feeling of it not hot: but supposing the same water to be frozen, 'twill doubtless then feel colder; and will any one say, that this is nothing but to feel it less hot? But it was not hot before, how, therefore, could it become less hot? To this we reply, that the organs of sense, consider'd in themselves, only receive impressions from outward objects, but perceive not what is the cause and manner of those impressions; the proper perception of causes belonging to a superior faculty, which judges whence the alterations made in the organs do proceed. Thus the eye represents a strait stick, part of it being under water, as if it were crooked; and two fingers laid cross one another, represent a single bullet roll'd between them, as if there were two; so that it is very possible, tho' the organ be manifestly and vehemently affected by the contact of cold water, yet the cause of that impression may, by reason, be judged to differ from that which the sense might to an inconsiderate person suggest. We must consider next, that sensations may, in several cases, be made, as well from alterations happening in the internal parts of the body, as from those which are manifestly produced in the external organ, by external objects; as appears by hunger, thirst, the great coldness that hysterical women complain of, in their head and back, and the troublesome cold which we every day observe, upon the first invasion of the fits of agues. I observe then, that tho' in a respective sense, the water, wherein the objection supposes the hand to be plunged, be cold, in regard its parts are less agitated than the spirits and blood in the hand; yet, in a philosophical sense, it is not quite destitute of heat, since it is yet water, not ice, and would not be a liquor, but by reason of that various agitation of its minute parts, wherein fluidity consists. Upon account of this respective coldness of the water, the hand is cooled; for the spirits and juices of that organ, meeting in the water with particles much less agitated than themselves, communicate to them some part of their own agitation, which they thereby lose; whence such a change is made in the organ, and in some other parts of the body, as is perceived by the mind, under the notion of coldness; being, indeed, an internal perception of the change happening in the organ. And if the water, wherein the hand is plunged, comes to be more cooled than before, the spirits, blood, and other parts of the hand, finding the aqueous corpuscles more slowly moved than formerly, must, according to the laws of motion, transfer to them a greater measure of their own motion, and, consequently, come themselves to be deprived of it: and upon this increase of the slowness of motion in the parts of the hand, there follows a new and proportionable perception of the mind, and so a more vehement sensation of cold. If then it be remembred, that upon turning one's eye to the dark part of a room, less enlightned than the window, tho' darkness be but a privation, and tho' the obscurity of that part be not absolute, but consists only in a less degree

PHYSICS.

of light; yet the action of the spirits, and other parts of the body, is so changed, upon occasion of the light's acting more faintly upon the organ than before, that the pupil is immediately and manifestly dilated; it will be no wonder, that where not only the spirits, but the blood, which circulates thro' the whole body, is disaffected, a great alteration should be felt in the hand, immediately exposed to the action of the cold water.

It might still be urged, that if cold be but a privation of heat, it is a privation of a strange nature; since it may be introduced into bodies, which were not hot before; nay, in some cases, into such as are naturally cold; and, by consequence, must have been put into a preternatural state, to be at any time hot. But since fluidity consists in the various agitation of the insensible corpuscles of a liquor, and heat in a tumultuary, and more vehement agitation of the insensible parts of a body; whence hot water scarce differs otherwise than gradually, from that which is cold to the sense; if cold be philosophically consider'd, it may well be said, that as long as water retains the form of water, and so continues a fluid body, tho' it may be very cold to the touch, yet it is not absolutely or perfectly cold; and, therefore, is capable of a farther degree of coldness, which it receives when brought to congelation; for till then, it was not destitute of those active corpuscles, requisite to keep it fluid; and till then, it was not absolutely or perfectly cold. Nor is it every glaciation itself, which brings liquors to be perfectly cold, in the philosophical sense of the word, so as quite to expel or subdue all the agile particles which were in the water, before it was turn'd into ice. For to effect this change, it is sufficient, that so many of these restless particles be destroyed or disabled, that there remain not enow of them to keep the water in a state of fluidity; so that the surplus may yet continue in the frozen liquor, and whilst there, perform several things; and by their recess, the ice may grow yet more cold. This notion suits very well with the different degrees of hardness observable in different portions of ice, sometimes upon account of the different degrees of cold in the same water or other substance. Thus having put a sealed thermometer into a glass, broader at the top than at the bottom, and oiled the inside, that the ice might not strongly stick to it, we poured in water, more than sufficient to cover the ball of the thermometer; then the water being carefully frozen, we observ'd where the spirit rested; and the instrument and ice being afterwards removed into the open air of a very frosty morning, the ice was taken from the ball; when presently the spirit subsided considerably below the former mark: which proves, that a degree of cold, sufficient to freeze water, may not render a body perfectly cold; this ice itself keeping the included ball warm, by fencing off the air, which at that time was considerably colder than it. And there is no sufficient cause assign'd, why many things, reckoned among privations, or

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negations, by the *Peripatetics*, as cold is by the *Epicureans*, may not admit of degrees no less than deafness, ignorance, &c. Thus in a total eclipse of the moon, when the earth, interposing between the sun and her, has first obscured her only in part, we generally complain of darkness in the air; but when the interposed earth proceeds to cover the remaining parts, and so makes the eclipse total, the darkness also is said to be much increased.

But if it be farther demanded, how a privation, or diminution of motion, can produce the effects we daily see produced by cold in the bodies about us; I do not pretend, that either an absolute privation of motion in a body, or a slowness of motion in the parts of it, is the proper efficient cause of the effects, vulgarly ascribed to cold alone: for cold is rather the occasion, than the true efficient of such effects, which are properly ascribed to those physical agents, whose operations happen to be otherwise modified, than else they would have been, upon account of that diminution, or slackness of agitation, which they meet with in cold bodies; whence they are both themselves deprived of the agitation they communicate to such slow bodies, and thereby act no longer as they would, were it not for that loss: and by a natural consequence of this change, which is made in themselves, they also modify the action of other bodies upon them: from which unusual alterations, happening in a world so framed as this of ours, and governed by such laws, with regard to motion and rest, as are observ'd amongst bodies; there must, in all probability, result many new, and some of them considerable phenomena. For tho' bodies at rest seem to have no action, which among corporeal substances appears to be performed only by local motion; yet bodies at rest themselves, may concur to great effects, both by determining the motions of other bodies, or by receiving their motion totally, or in part, and so depriving the moving bodies of it. Thus the arches of a bridge, tho' immoveable themselves, may, by guiding the water of the river which beats against them, occasion a rapid and boisterous stream, able to drive the greatest mills, and perform more considerable effects, tho' the river, before it met with such obstacles, ran calmly. And tho' water has its parts in perpetual motion among themselves, yet since that agitation is exceeding slow, in comparison of the swiftness of a cannon-bullet; such a bullet discharged but little above the level of water, often rebounds from the surface of it; and, consequently, from thence receives a new determination. Thus, farther, suppose upon a stream there were built many different mills, and the current was by some contrivance diverted another way; must not the action of all these mills necessarily cease too, tho' this change be not produced by any positive and direct violence offer'd to the mills, but only by preventing the impulse, requisite to keep them in motion? In paralytic affections, where a viscous humour obstructs a nerve, tho' its proper and immediate action be only to hinder or weaken the spirits, which pass'd freely

PHYSICS.

along that nerve to the muscle, whereto it leads; yet the action of the other parts of the body, and the relaxation of the fibres, often produce a tremulous motion in the limbs, and distortion of several parts. But it comes up much nearer to our purpose, that animals dye in the exhausted receiver, merely by a privation of air, in a very few minutes, without the intervention of any positive agent. To sum up the result of these instances, it appears, that the effects undeserv'dly ascribed to cold, need not to be referred to a privation, but to those positive agents, or active causes, which by their own nature are determined to act otherwise on, or suffer otherwise from one another, in cases where there is a great hindrance, or cessation of the usual motion, than where there is not.

'Tis farther argued against us, that supposing the hand plunged first into hot water, and then into cold, why is it not cooled as well in one case, as in the other? Is it because the heat of the hand shrinks inward in the cold water, and therefore the hand is left less hot? But what has heat to fear in the cold water, unless it be cold? Now if cold be only a privation, what can it do to heat? A privation is nothing, and therefore cannot affect its motion. This objection, indeed, might puzzle some school-philosophers, but may be thus answer'd. When a man puts his hand into warm water, the agitation of the corpuscles of the liquor surpassing that of the spirits, blood, and other parts of his hand, cannot but excite in him a sense of heat; but when he puts the same hand into cold water, the case ought to be much altered, not from any imaginary retreat of the spirits, but the communication of motion by other parts to the surrounding water, by which means there must happen in the hand a great decrease of the former agitation of its parts; the perception or sense of which decrease of motion is that which we call feeling of cold.

There is another argument, drawn from the way of artificially freezing water, by a mixture of snow and salt, placed about the outside of the glass, containing the liquor; whence 'tis concluded, that, since this mixture is thro' the glass able to freeze the water into ice, it may as justly be affirmed to act by corpuscles of cold, as fire can be said to act by calorific corpuscles; when kindled coals, placed on the outside of the glass, make the contained liquor boil. This, indeed, seems very plausible, but not clear and cogent; for it is not so evident, that ice and salt act by a positive quality, as that burning coals do so; tho' cold seems as well to be produced by the former, as heat by the latter. Innumerable experiments shew, that heat is a positive quality, consisting in a tumultuary and vehement agitation of the minute parts of the body, said to be hot, and producing also in the bodies, whereto it is communicated, a local motion, which is manifestly a positive thing; and by the confession of nature herself, in many instances, heat is a positive quality: but that cold is so, doth not appear even by artificial conge-

congelation. For all that is clear in the matter of fact, is, that snow, or beaten ice, and salt, are put about a vessel full of water, and that soon after, this water begins to turn into ice; but that this glaciation is performed by swarms of atoms of cold, which permeating the glass, invade and harden the liquor, is not perceived by sense, but concluded from reason. So that if another intelligible way can be proposed, fairly to explain the phenomenon, besides that, the objection drawn from this experiment against my hypothesis, will be invalid. And such an explanation M. *Des-Cartes* affords us: the subtil matter, says he, which surrounds this water, being more gross, and consequently more forcible than that which stuck about the parts of the snow, possesses its place, whilst the parts of the snow roll about the parts of the salt in the act of dissolution; for it moves more easily thro' the pores of salt water than of fresh, constantly endeavouring to pass from one body to another, in order to come where its motion may be the least resisted; whence the more subtil matter goes from the snow into the water, to succeed that which went out there; and being unable to continue the agitation of the water, suffers it to congeal. And this bears analogy to the practice of drying precipitates upon brown paper, or pieces of brick, or chalk; which hasten the exsiccation of the things laid upon them, not by any drying particles they emit into the soft substances, but by imbibing the superfluous parts of the liquor of the substances to be dried. Thus I have immersed a piece of soft bread into an actually cold liquor, that would hastily imbibe its aqueous corpuscles, and dry it, in a minute or two, so as to make it feel hard. And by putting into weak spirit of wine a sufficient quantity of salt of tartar, the spirit will be dephlegmed without distillation, or so much as heat; which the better illustrates the *Cartesian* explanation; because, by the change made of the greater part of the salt of tartar into a liquor, which will not mix with the spirit of wine thus rectified, it is manifest, that the aqueous particles of the weak spirit, more readily continuing their motion among the fixed corpuscles of the salt, than the vinous ones of the spirit, they pass into the alkali, and dissolve it; and thereby desert the liquor, thro' which they were before diffused. And there is another saline body, which so unites with water, as not to be, by the eye, distinguished from it, yet it is of such a texture, that water will forsake this body it kept in agitation, to pass into spirit of wine, and so leave that, which it kept in the form of a liquor before, to appear in the form of a consistent body; which comes nearer the proposed experiment of glaciation. But this is yet farther illustrated by the fusion of camphire into a liquid, with the steam only of *Aqua fortis*, or spirit of nitre, and the recovery of its consistence, by pouring common water to it; for that these spirits are not sensibly warm (no more than the *Cartesian materia caelestis*) in water,

PHYSICS.

water, is manifest to the touch. And tho' I at first suspected, that the reason why pouring this oil into water, presently reduces it to camphire again, might be the coldness of the water; I afterwards found it rather owing to the nitrous spirits being disposed to pass out of the oil into the water, whilst the liquor readily imbibed and diluted them, and consequently disabled so many of them, that those which remained, could not any longer perform their office; since the reduction of the oil into camphire would presently be made, tho' that liquor were not poured into cold water but hot: so that the agitation, which it received from the particles of the menstruum, tho' not to the touch sensibly warm, was much more efficacious, than that it received from the heat of the water. There may also be corpuscles of such a nature, in their size, shape, and other attributes, as to be fit to enter the pores, and pierce even into the inward parts of water, and some other bodies, so as to expel the calorific corpuscles they chance to meet with, or to clog, or hinder their activity, or, on some other account, considerably lessen that agitation of the minute parts, by which the fluidity of liquors, and the warmth of other bodies is maintained. But, even in such cases, tho' the agent and the actions, which produce coldness, are positive things; yet the nature of coldness itself may consist in a privation. Thus, when a man is killed by a bullet, his death is effected by a positive, and even impetuous action; yet death itself is but a privation of life. If also in a dark room, a man cast cold water upon a burning coal; tho' the water acts by its positive quality of moisture, and, by virtue of that, extinguishes the fire, and so destroys the light; yet the darkness, consequent upon this action, is not a positive thing, but a privation.

The last argument that remains to be consider'd is this. Tho' many things seem to grow cold upon the bare absence of heat, yet unless an external cold be introduced into them, they do not so properly grow cold, as lose a degree of heat. Thus a stone, or a piece of wood, which we suppose neither cold nor hot, will become hot when applied to the fire; but when that heat ceases, and nothing cold is near them, we may properly say they are become less hot, and return to their own state, not that they grow cold. But this seems to be a dispute about words. If we speak only of a coldness as to sense, I see not why any body, that is heated by the fire, may not upon its removal thence be said to grow cold, and not barely to lose its heat. For the sensible coldness of water, consisting in a diminution of the motion of its corpuscles, that cease to be as much agitated, as those of our organs of feeling; if this impaired agitation be still more lessened, the liquor will still grow colder, without the help of any positive cause, till at length the agile parts, which kept it fluid, being quite expelled, or disabled, the form of the liquor comes to be exchanged for that of ice. To that part of the argument, which proposes an indifferent

ent body, that, when affected with an adventitious heat, would not grow cold by the bare removal, or cessation of that heat, unless it were cold by an agent, positively and actively cold; we reply, that it is one thing to propose such a neutral body, as a possible thing; and another to give instances of it, in particular bodies, wherein that neutrality is not to be found. But if a body should be proposed as adiaphorous with regard to heat and cold, I might say, that if such an one should be carried into a hot place, it might there grow warm; and if removed back again, and kept till it lost that new adventitious heat, it might rather be said to lose its heat, than grow cold, as to sense. The reason is, because every diminution of heat, cannot denominate a body cold, but only such a degree as reduces the parts of it to a fainter motion, than is at that time in those of our organs of feeling; and till this is done, the body proposed is still in a state of heat, as to sense; tho' in regard of other bodies, it may then be naturally cold. Thus lead, which hath but heat enough to keep it in fusion, may, by the pouring on of such water, as to a man's hand would feel hot, be brought to grow hard; which loss of fluidity is also the natural effect of cold, tho' perhaps both the metal and the liquor be yet, as to sense, considerably hot. So that this controversy seems to be rather verbal than real, and may be determined by settling the distinct acceptation of the words cold and heat.

But notwithstanding these answers to the arguments, all of them alledged by the learned *Gassendus*, many difficulties remain with me, particularly as to the production of cold, by corpuscles of cold. I shou'd be gladly satisfied whether, and on what account, those little fragments of matter are cold? Whether those frigorific particles, which must in multitudes crowd into water, to turn it into ice, have gravity or levity, or are indifferent to both? What structure the corpuscles of cold are of, to make them frigorific to that innumerable variety of bodies, they are said to pervade? Whether the frigorific faculty of these corpuscles may be lost or not? Whether they are primitive bodies; and if not, whether there was no cold in the world, before they were produced; and whence that cold could proceed? And lastly, if they are said to be primitive bodies, how it comes to pass, that by putting a certain factitious body actually warm, into water, which was also warm, there should presently ensue an actual coldness?

But there are two grand problems relating to this subject, which I require to be solved. The first is, how, upon the mixture of two or three bodies, there should manifestly ensue a great and tumultuary agitation of small parts, yet even during this conflict, not any sensible heat, but a considerable degree of cold be produced, and that even in the internal parts of the mixture? This might tempt one to ask, whe-
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PHYSICS.

ther local motion is, in its own nature, a generical thing, which may be so diversified by circumstances, that one kind of modification of it, as it is made in corpuscles of several sizes and shapes, may be the cause of heat, and another that of cold. What gives rise to this problem is, the following experiment. We took two or three saline bodies, each of them purified by the fire, and mixing them together in a due proportion, they produced what to the eye appear'd a great effervescence; but tho' the hissing noise were laid, and the numerous bubbles suddenly generated made the matter apt to over-flow the glass, if small, or the ingredients hastily put in; yet even whilst this ebullition lasted, the containing glass felt extremely cold; so that even in winter, the outside of it wou'd be quickly cover'd with large drops of dew, gain'd from the external air, which afterwards uniting, trickled down by their own weight: and by gradually throwing more of the ingredients upon each other, we cou'd prolong the experiment at pleasure, and that at various seasons of the year. And once taking two deep glasses, I put a quantity of fair water, of the same temper with the ingredients, in the one, and some of our saline mixture into the other; and letting down a thermometer into the water, to acquire the temper thereof, I rais'd it up by its string, and placed it in the mixture that was then hissing, and filling its containing vessel with bubbles, upon which the tinged spirit subsided from four inches $\frac{1}{4}$, to $1\frac{1}{2}$ inch. Then removing the thermometer into the common water again, the spirit soon mounted to above $4\frac{1}{2}$ inches. And this I twice repeated with the like success. So that the coldness of this mixture, was far from being a deception of the sense. And to shew how much this strange coldness depends upon the peculiar texture of the mixture, or of its component particles, I took the remaining part of the acid liquor that went to compose the mixture, and put thereto a convenient quantity of fair water of the same temper; but they scarce, upon this, sensibly differ'd in coldness, when examin'd by a good sealed thermometer. Some of the pure salt, also, used in the mixture, being added to water in the like manner, gave no manifest signs of an increased coldness; no more than the glass wherein I usually kept a large quantity of our salt: whence the coldness of the mixture cannot be attributed to either of the ingredients apart, but is a quality arising from their union. And when I had left some of this mixture, for a night, in the same room with a glass of fair water, and a good sealed weather-glass; I cou'd not in the following morning, when the tumult of the contrary salts of the mixture was ceased, perceive any considerable difference betwixt the coldness of that, and of the water. And having, instead of the salt I hitherto employ'd, mix'd some of the very strong spirit of this salt, and which used to come over therewith in distillation, with a spirit drawn for the purpose, which seem'd exactly like the other I had also hitherto used, being made wholly in

in the same manner, the mixture of these two, instead of growing hot, became warm, and suddenly impell'd the spirit in the thermometer, from three inches to above eight. And the like contingency I have at other times found in making the experiment. On the other hand, the ingredients used herein, wou'd produce a manifest coldness, tho' the salt were first well warmed by the fire. The way of preparing these liquors and salts, I am obliged to conceal; but to shew the same phenomena in a less degree, I put to very good salt of tartar, a convenient quantity of the spirit of vinegar, tho' I am not sure that this will always succeed.

My second problem is this, from whence proceeds [the vast force of freezing water? For, resisting bodies being to be broke by a violent local motion, and cold either consisting in, or at least being accompanied with a privation, or a great diminution of motion; it seems very difficult to conceive how it should make water exert so wonderful a force. *Gassendus* indeed teaches, that glaciation is performed by the entering of swarms of corpuscles of cold into the liquor; but I much doubt this solution: since these atoms of cold seem not to make that expansion of the water required; for though water will be more refrigerated, as the air grows colder, yet till it be brought to an actual glaciation, all the swarms of the frigorific atoms in it, are so far from expanding it, that they more and more condense it. And even that degree of cold, which destroys fluidity, tho' it expands water, does not do it merely by the multitude of the frigorific corpuscles, which invade the pores of the fluid body; since pure spirit of wine, and almost all chymical oils, tho' exposed to the same degree of cold, that turns water into ice; and, as I have tried, to a far greater degree, than is necessary for that purpose; will be the more condensed by those swarms of particles. But, what is more considerable, I have carefully observed, that, besides common, or express'd oils, chymical oil of aniseeds itself, being frozen by an intense degree of cold, will not be expanded, but greatly condensed, and accordingly grow specifically heavier than before. But no liquor besides water will swell by cold; nor will water itself do so upon every degree of cold, but only upon so great an one, as actually turns it into ice: and upon the freezing of water, we may observe in the ice many bubbles, supposed to be aerial, intercepted between the solid parts: which supposition, if true, would perhaps raise a suspicion, that the air contained in these bubbles might have an interest in the phenomenon; since I have found by trials, purposely made, that air gather'd into visible portions, may exercise a considerable elasticity, that appeared not, whilst it was invisibly dispersed in the water. To demonstrate, that freezing water has actually an expansive force, we shall here add an experiment of the same nature, with some formerly mention'd to the like purpose; and more fully repeat two or three others, which were made to measure this force.

PHYSICS.

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And first, I caused the barrel of a short gun to have a screw fitted to the mouth of it, by which we might easily stop it, as we did the touch-hole after another manner; then filling the barrel with common water, and exactly closing it by the help of the screw, we laid it in a convenient vessel, where 'twas encompassed with a frigorific mixture of snow or ice, and salt; and in a short time we found the barrel burst; part of the ice appearing along the gaping crack, made in the body of the iron by the freezing water. But to measure this expansive force,

2. We took a strong cylinder of brass, its cavity two inches in diameter; into this was put a bladder of a convenient size, containing a quantity of water, so that the neck of it being strongly tied, the water might not get out into the cavity of the cylinder, nor be able to expand otherwise than upwards. Into this cylinder we fitted a wooden plug, turned on purpose, which was somewhat less in diameter than the cylindrical cavity, that it might rise and fall easily in it. Upon the upper part of this plug was laid a conveniently-shaped flat body, whereon were placed several weights to depress, and hinder its rising by the expansion; then a frigorific mixture being applied to the cylinder, it appeared, within about half an hours time, (by a circle, which had been purposely traced on the side of the plug, where it was almost contiguous to the orifice of the cylinder,) that the water in the bladder began to expand itself; and in two hours after, the circle appeared to have been raised near half an inch, notwithstanding one hundred and fifteen pound weight, that endeavoured to hinder the ascent.

3. At another time using the like apparatus, the cylinder being $3\frac{5}{8}$ inches in diameter, and in depth four inches, we took out the bladder, and found the cylinder of water within it not wholly frozen, some liquid parts appearing about the centre; which liquor, if we had not too soon desisted from the experiment, might probably have raised the weights somewhat higher. The ice here being in length but three inches, and $\frac{1}{8}$; yet so small a quantity sufficed to raise, besides the board whereon it rested, an hundred pound weight *Averdupoize*.

4. We repeated this experiment, and now the plug raised two hundred and fifty four pound weight.

The End of the First Volume.

20 JUL 65

